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ABSTRACT

Existing management techniques hold vast potential for improving
construction operations. This thesis examines the influence on
managerial decisions of the backlog of work. The thesis studies
a model developed by Larew that relates the work completed by an
enterprise and the backlog of work in order to gain an insight
into the influence of the backlog of work on construction company
operations.

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THE INFLUENCE OF THE BACKLOG

OF WORK ON CONSTRUCTION COMPANY OPERATIONS

A Thesis

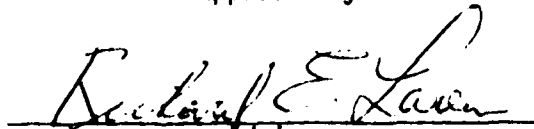Presented in Partial Fulfillment of the Requirements
for the Degree Master of Science

by

Ralph Clifton Rhye, B.S.C.E.

The Ohio State University
1980

Approved by

Adviser
Department of Civil Engineering

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CHAPTER 1

INTRODUCTION

1.1 The Construction Industry Today

The construction industry is a powerful and extremely competitive segment of the United States economy. "The value of construction put in place has averaged 13-14% of the total gross national product in recent years. In terms of employment, the construction industry is the largest single industry in the country, employing some 6,000,000 people at one time or another during a single year" (24:277). Economic conditions that have prevailed since the late 1940's have spurred significant growth in the industry and today "there are approximately 75,000 design firms, 800,000 contractors, 100,000 material suppliers and 1,000 equipment suppliers" (24:280). The industry is characterized by extremely low profits and high rates of failure. Approximately 1600 construction firms fail each year (32:6), while countless others manage to barely survive. From 1967 to 1976, the industry's average share of total business failures has remained steady at 17% (32:5) while the average net profits on sales for construction firms ranges from 1-2% (15).

Many researchers and industry personnel believe that the miserable conditions in the industry are primarily caused by managerial incompe-

tence and a failure to develop and adopt new or improved management techniques. Rossow and Moavenzadeh paint a grim picture of the industry in the following passage (24:291):

> The construction industry is generally considered to be rather slow in its acceptance of new management techniques; network techniques comprise probably the most significant advance to date, but even these are not being used to their fullest extent. Other sophisticated techniques which are still talked about more than they are used but which appear to be generally applicable to the construction industry are, for example, bidding strategies, time and motion studies, methods engineering, value engineering, resource allocation, operations research, advanced estimating techniques and systems management techniques. The construction industry is also beginning to use the computer.

The techniques mentioned above and most of the research in construction address two of management's primary functions, planning and control at the project level. Managerial emphasis in construction has traditionally been placed on the time period between project inception and completion and the majority of managerial energy is consumed by field activities (7:4).

Unfortunately, the economic conditions that have prevailed up to the 1970's are changing dramatically (4:647), and managerial emphasis solely at the project level may prove inadequate in a highly competitive environment. Construction markets are becoming more competitive as the industry's ability to supply services becomes greater than the demand (4:647). Volatile economic conditions pose a serious threat to the survival of the individual firm due to costly and scarce credit and a reluctance of buyers to purchase construction services. No firm, regardless of age and experience, is immune from environmental pres-

sures that may lead to failure (15): the firm can only adapt and improve company operations at all levels in hope of surviving and, possibly, prospering in the industry today.

1.2 Motivation for Research

There is little doubt that existing management techniques hold vast potential for improving construction operations. It is the writer's conviction, however, that greater research effort must be devoted to the examination and exploration of com. .y operations at the highest decision making levels. New models and management techniques must be developed that address such issues as marketing analysis, portfolio design, project feasibility and desirability ranking, organizational design, etc. Issues such as these have for the most part been largely neglected in the construction literature. Short of developing new models, it may be feasible to modify existing models to address issues that confront top construction company executives today.

An issue that has been neglected by researchers that influences many managerial decisions in some manner is the backlog of work. The purpose of this thesis is to study a model developed by Larew (14) that relates the work completed by an enterprise and the backlog of work (14:104) in hope that some insight may be gained into the influence of the backlog of work on construction company operations.

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1.3 Organization

Chapter 2 presents an introduction to the backlog of work model. Sections 2.1 and 2.2 discuss model parameters and the impact of changes in these parameters on the backlog of work curve for a given operation. Section 2.3 presents a brief review of past applications of the model and potential applications of the model are summarized in Section 2.4.

Chapter 3 further examines the topics identified in Section 2.4. The current literature on each topic is reviewed to promote and under-standing of the state-of-the-art in addressing and confronting these issues. The need for research is discussed for each issue. Section 3.2 examines competitive bidding and the backlog of work, Section 3.3 examines project size and Section 3.4 discusses working capital and bonding capacity.

Chapter 4 outlines the experiments performed by the writer. Sections 4.1 and 4.2 briefly discuss the computer programs used during the course of study. The assumptions for all experiments are outlined in Section 4.3. The scope of research is outlined in Section 4.4 and the experiments are discussed in Sections 4.5, 4.6 and 4.7.

The results of the experiments performed by the writer are report-ed and discussed in Chapter 5. Chapter 6 presents the writer's conclu-sions and recommendations for future research.

CHAPTER 2

THE BACKLOG MODEL*

The purpose of this chapter is to introduce the reader to the backlog of work model. Development of the model is discussed in the first section. The next two sections discuss the parameters in the model and the impact of changes in these parameters on the relationship between the work completion rate and the backlog of work. Applications of the model by other researchers are summarized in the third section and potential applications of the model are presented in the last section.

2.1 Development of the Model

Larew's model suggests that the amount of work completed by an enterprise in any month is a function of the backlog of work at the beginning of the month. Backlog is defined as the amount of uncompleted bonded and unbonded work on hand, and may include work that has been bid but not yet awarded. Work that has been subcontracted and bonded by the subcontractor's surety is not included in a general contractor's backlog of work. The relationship developed by Larew is

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*The material presented in this chapter is from the work of Larew (14). Citations within this chapter are given for direct quotes only. All paraphrased material is not cited within the text.

$$W = CUe^{-KU} \qquad (2.1)$$

where   W = The work completed during the month in thousands of dol-
           lars,

        U = The uncompleted work on hand at the beginning of the
           month in thousands of dollars,

        C = A constant of proportionality,

        K = An uncompleted work coefficient, and

        e = 2.71828 (the Napierian base).

The source documents for Larew's original study were the monthly and

annual financial statements from a general contracting operation for a

period of 60 months during the 1960's. The information recorded was

accumulated completed work versus time, to include billings plus the

completed portion of work in progress not yet billed, and the sum of

the completed work and backlog versus time.

Figure 2.1 shows a typical relationship between W and U. The work

completed by an enterprise in any month is not likely to be determinis-

tic: seasonal conditions, change orders, personnel turnovers, equip-

ment failures and an endless number of factors combine to ensure that

the work completed by an enterprise in any month is stochastic. It is

important to note that the relationship between W and U is constrained

in all directions. The work completed by an enterprise in any month

will range from zero to some level of production that is constrained by

the availability of working capital. This level, which is a measure of

the mean completion rate, is referred to as the working capital con-

straint level or level of capitalization. It is possible for a company

WC -- Working Capital Constraint
BC -- Bonding Capacity

WORK COMPLETION RATE

WC

BACKLOG OF WORK

BC
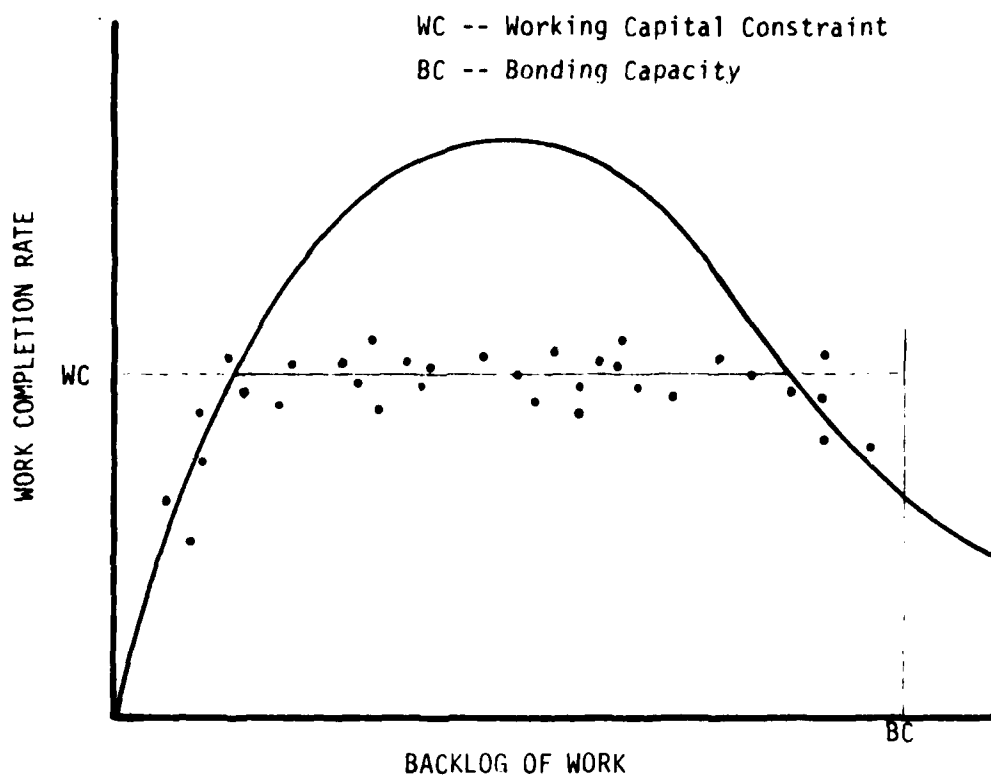
FIGURE 2.1 -- TYPICAL W VERSUS U CURVE

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to complete a negative amount of work in any month if initial work is rejected for noncompliance with the contract documents or if work is somehow damaged or destroyed; however, these exceptions are not examined in this thesis. The backlog of work will range from zero to a bonding limit that is established by the company's surety. These constraints will be discussed in further detail in Chapter 3.

2.2 The Uncompleted Work Coefficient

Larew found that the uncompleted work coefficient, K, was a "measure of the time required for making decisions and providing information required by field personnel" (14:113). The coefficient is therefore called the decision making time interval parameter. The importance of rapid decision making and good communications is emphasized in nearly every text addressing construction company planning. The timeliness of decision making depends on such factors as the mode of operation (modus operandi), the type of work being performed, the performance of the owner and Architect/Engineer and the contractor's information gathering and analysis system. The functional relationship between the above factors and the decision making time interval was not analytically studied, but a study of the company's history provided valuable insight into changes of the decision making time interval with changes of modus operandi. Table 2.1 presents a summary of Larew's study of the decision making time interval. Figure 2.2 shows the effect of changes in the decision making time interval parameter while the constant of proportionality remains constant.

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TABLE 2.1 -- ESTIMATING THE DECISION MAKING TIME INTERVAL

K	ESTIMATED DECISION INTERVAL	MODUS OPERANDI
.000144	1-Day	Design build; decisions usually made on the spot or within hours
.000691 .000706	1-Week	Conventional competitive bidding mode; planning and scheduling by means of a real-time information system
.001516 .001725	2-Weeks	Design build and conventional competitive bidding modes; transitional period during implementation of a real-time information system
.003029	4-Weeks	Design build and conventional competitive bidding modes; one major project experiencing continued delays due to the lack of a qualified owner representative in the field with authority to make decisions; owner delaying project due to unanticipated higher cost
.003708	5-Weeks	
.004143 .004261 .004450 .004452	6-Weeks	
.006134	8-Weeks	Changeover in top management personnel; actual time to make decisions varied greatly

2.3 The Constant of Proportionality

Larew found that changes in the constant of proportionality, C, were associated with personnel changes and external forces. Production tended to decrease when key personnel left the enterprise or when external forces, such as social pressures or threats of violence, were directed against the enterprise. Other factors such as promotions also appeared to be associated with changes in the constant of proportionality. The constant of proportionality is, therefore, called the perceived opportunity for achievement parameter. Again, the functional relationship between the above factors and the parameter was not analytically studied, but the company's history provided some insight into changes of the parameter with changes of the attitudes of key personnel. Table 2.2 presents a summary of Larew's study of the perceived opportunity for achievement parameter, and Figure 2.3 shows the effect of changes in the parameter while the decision making time interval parameter remains constant.

2.4 Applications of the Model

The writer finds no published construction company applications of the backlog model or any similar model other than the original work of Larew (14). However, Hunt (13) has applied the model in his study of the operation of the Building Research Laboratory at The Ohio State University, and Larew has applied the model in a limited number of unpublished proprietory studies of construction companies. According to Larew, the major obstacle to application of the model is that company records typically do not contain data needed to accurately reconstruct
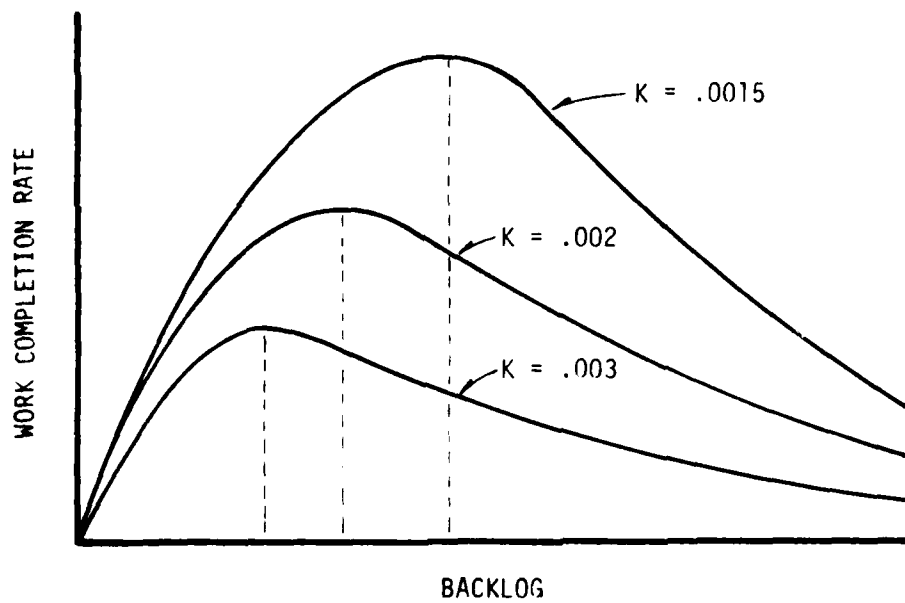
FIGURE 2.2 -- EFFECT OF CHANGES IN K
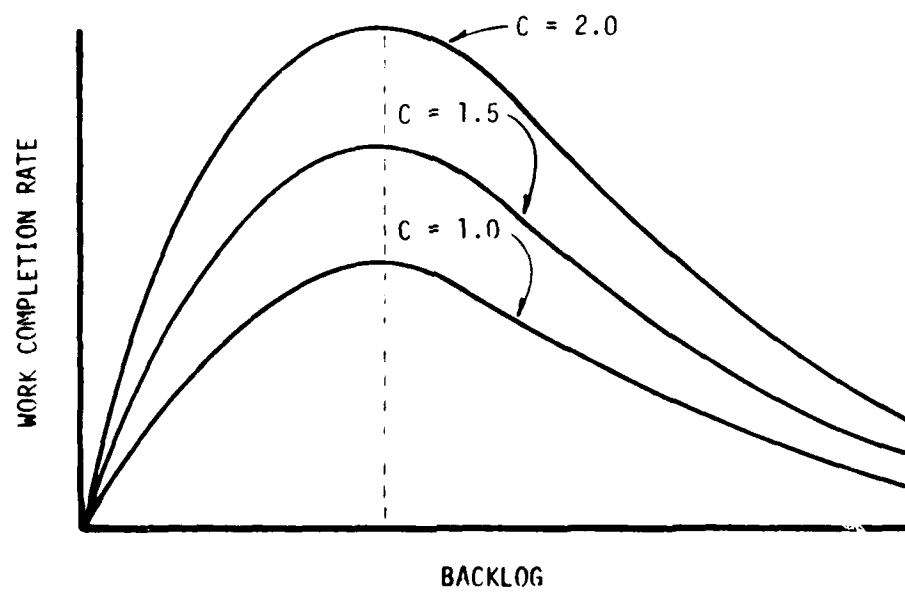
FIGURE 2.3 -- EFFECT OF CHANGES IN C

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TABLE 2.2 -- ESTIMATING THE PERCEIVED OPPORTUNITY FOR ACHIEVEMENT

C	PERCIEVED OPPORTUNITY FOR ACHIEVEMENT	COMPANY HISTORY
2.058 2.055	Excellent	Enterprise expansion; personnel at all levels within the organization are working at their fullest potential
1.551 1.264 1.205	Good	Layoffs are occurring but personnel are still working at capacity; several key personnel are promoted and in training
0.776 0.742 0.599 0.523 0.453	Average	No special opportunities or inhibitors
0.186 0.113	Poor	Opportunities abound but workers feel stiffled due to new auto-cratic management style; inter-personal communications break down

both the rate of work completion and the backlog of work.

Larew has recently applied the model in studies of individual projects. His most recent unpublished studies concern private and public construction in Kuwait. White (31) recently applied the model in his study of the construction of a twin nuclear power plant. While the writer does not examine applications of the model at the project level, the applications summarized above tend to support the validity (usefulness) of the model at both the enterprise and project levels.

2.5 Potential Applications of the Model

Larew originally suggested that the model may provide some insight into determining if the optimum markup should be modified with respect to the level of backlog if a firm's primary objective is to maximize net profits. To examine this topic, he suggested that a computer program be written to incorporate the model into a competitive bidding strategy. Constraints on the work completion rate and the backlog of work suggest that the model may also be used to examine working capital and bonding constraints and the influence of project size on net profits. The model appears to be adaptable for the study of a wide range of topics; however, research in this thesis is limited to the above issues.

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CHAPTER 3

POTENTIAL APPLICATIONS OF THE MODEL

The purpose of this chapter is to introduce the reader to the
three areas of study in this thesis as they relate to the backlog of
work: competitive bidding, project size, and working capital and bonding
capacity. The current literature for each topic is reviewed and exam-
ples are presented to promote an understanding of how the backlog model
may be used to study each issue.

3.1 The Competitive Bidding Process

The construction contractor may obtain work through the negotia-
tion or competitive bidding processes. While there has been a gradual
increase in the amount of negotiated work, the submission of sealed
competitive bids remains the predominant method of obtaining work in
most construction markets (11:181). In this process the owner will
normally award the contract to the lowest qualified bidder. The
dilemma facing the contractor in the competitive bidding process is
quite simply understood. The contractor must estimate the cost of a
complex product or service before it physically exists, and then deter-
mine a markup that will be added to the cost estimate. The contrac-
tor's understanding of the cost of a given project is complicated by
the dependency and complexity of work items that comprise the project,

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his experience with similar work, the accuracy of his cost records, a technological advantage or disadvantage and a variety of other factors. If the contractor's estimated cost is too high, the probability of obtaining competitively bid work is decreased. If the estimated cost is too low, the contractor's probability of winning is increased, but the probability of showing a profit is decreased. A similar analogy can be made with the markup. The markup to be added to the estimated cost should reflect the contractor's objectives, the cost of estimating the specific project and others that were estimated and lost, the cost of overhead and other non-price features, such as, the backlog of work.

3.1.1 Competitive Bidding Strategies and the Backlog of Work

It has been observed that contractors typically increase the markup applied to an estimate as the backlog of work increases and decrease the markup as the backlog of work decreases. For companies using expectancy pricing methods, this means that the markup which maximizes expected profits is not always used and that some markup is used that reflects the financial or managerial position of the firm, market conditions or some combination of secondary objectives. Since Friedman's pioneering effort to develop a formal bidding strategy, several researchers have recognized the need to incorporate a company's work load (backlog of work) in an analytical bidding strategy (2, 3, 11, 14, 21, 25, 26, and 30). All currently published competitive bidding strategies developed for use by the construction industry require the interjection of subjective decision making at some point in the

analytical process to account for such intangibles as the backlog of work, self-imposed constraints on project size or the number of projects bid, or secondary objectives other than that of maximizing expected profits or expected utility. Bacarreza notes that markup should be modified to account for such intangibles, but does not specify how or to what extent markup should be modified (2:29).

Grinyer and Whitaker present a schematic of the competitive bidding process (11:183), shown in Figure 3.1, that recognizes the backlog of work and the limited resources of the contractor as key variables in the bidding process. A contractor should first examine these key variables to determine if an opportunity will be competitively bid. If the opportunity is deemed favorable and within the company's capacity, the project is estimated. After the estimate is complete, the contractor should again examine his backlog of work and current resource utilization to aid in developing the markup that will be applied to the estimate. Managerial judgment is required throughout this process to determine how and to what degree the backlog of work should influence the competitive bidding process.

Wade and Harris (30) suggest a similar process that recognizes a variety of constraints, to include the backlog of work, that influence a contractor's competitive bidding strategy. They state "that it would be naive to develop a business strategy without including, at least implicitly, effects caused by such constraints" (30:202). Unfortunately, implicit consideration is also outside the development of their LOMARK bidding strategy.

```
                      ┌─────────────────────────────────────┐
                      │      External Environment            │
                      └─────────────────────────────────────┘
                          ┌──────────────────────────┐
                          │       Competitors        │
                          └──────────────────────────┘
                              ┌────────────┐
                              │ Industry   │
                              │ Resource   │
                              │ Suppliers  │
                              └────────────┘
```

Decision to Tender (Selection decision) → Estimating → Adjudication

Current Company Position
-work load
-resources

CONSTRUCTION COMPANY

CLIENT

Reject

Bid

— — — ► Information flows
————► Sequential flows
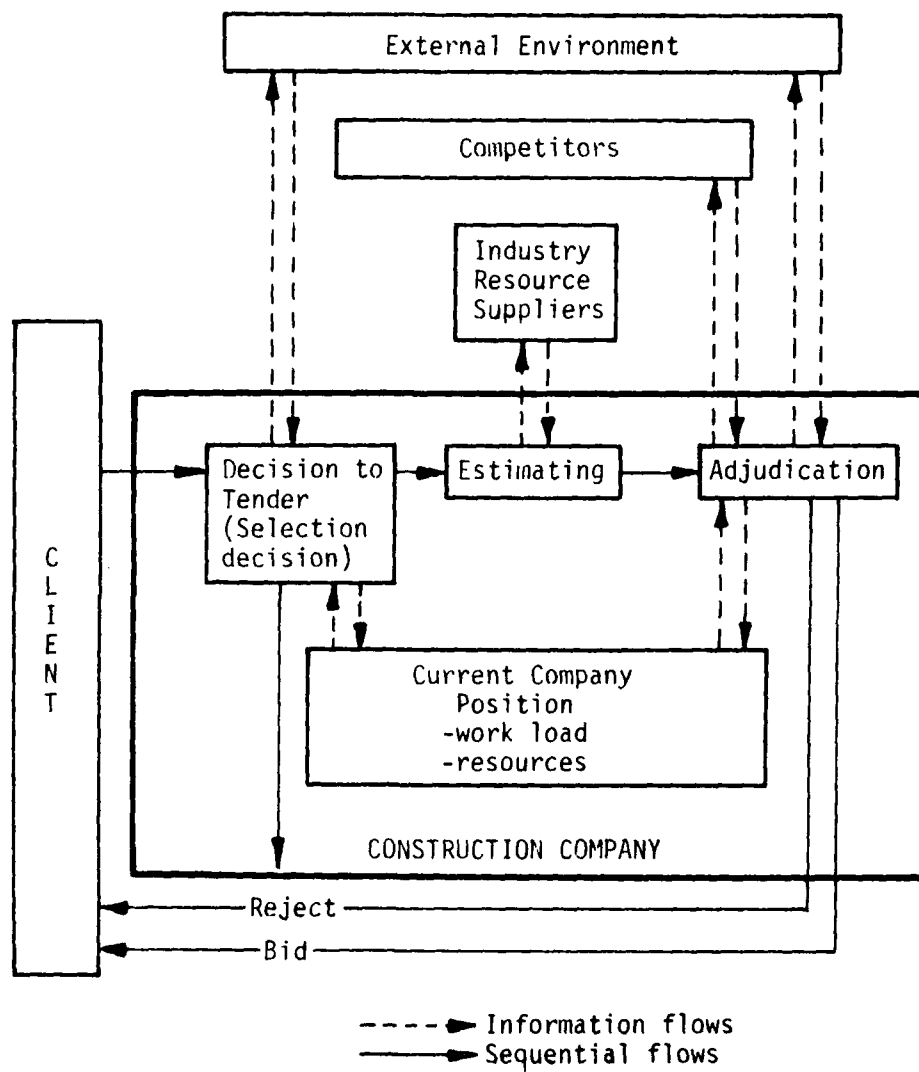
FIGURE 3.1 -- THE COMPETITIVE BIDDING PROCESS
(11:183)

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The works of Sewall (25) and Larew (14) in the area of competitive bidding perhaps best illustrate the state of the art in considering objectives other than the maximization of expected profits. Sewall developed a computer program that utilizes his competitive bidding strategy to analyze market opportunities. He notes that "in the long run, the contractor's best profit maximizing strategy is to make bids which have the greatest expected contribution on each contract opportunity" (25:95). Sewall's clientele, however, tend to view the computer model as a tool used only to perform complex mathematical calculations, and they express the need to exercise professional judgment at both the input and output stages of the program. As a result, the output is designed to display a range of bids and the corresponding probabilities of winning and expected contributions. The contractor is able to determine the change in the expected contribution if he bids slightly higher or lower than the bid which maximizes the expected contribution. Using this approach, the contractor is able to subjectively explore the impact of secondary objectives and non-price features, such as the current utilization of capacity, on the probability of winning and the expected contribution (profit).

Larew's competitive bidding strategy does not explicitly examine secondary objectives or the backlog of work; however, he does suggest that the probability density function of markup may be used to examine the impact of such factors on the expected profit at various levels of markup. Figure 3.2 presents a typical probability density function for markup. M* in this figure is the markup which maximizes expected net profits. Larew recommends that a contractor should not bid below M' or

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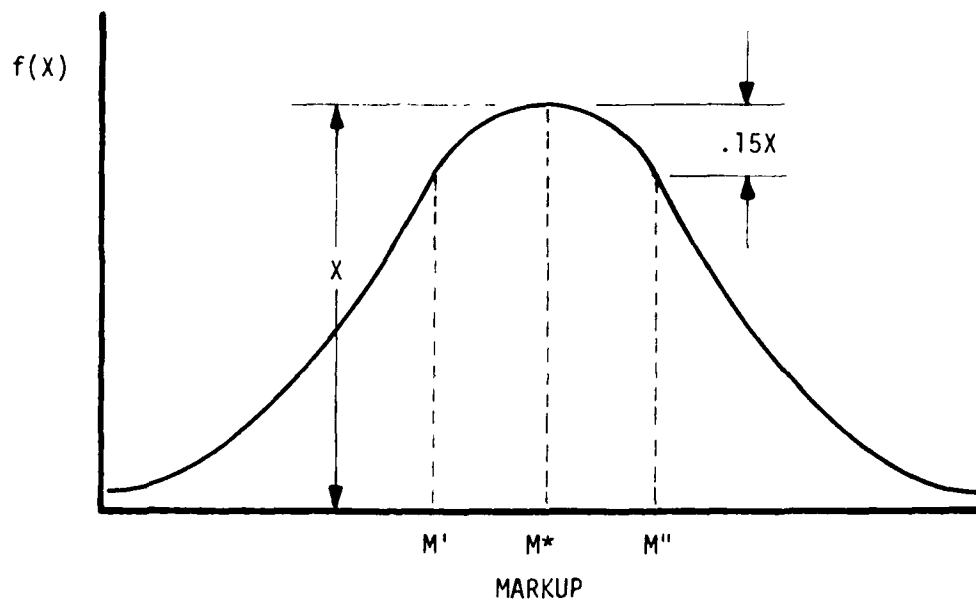
FIGURE 3.2 -- PROBABILITY DENSITY FUNCTION FOR MARKUP

above M" after considering secondary objectives, and these two markups are found where a horizontal projection intersects the probability density function at 85% of the maximum frequency, $f(x)$.

3.1.2 Other Related Research

The works of several other researchers in areas related to competitive bidding merit discussion for their consideration of the backlog of work. Vergara and Boyer (29) present an initial attempt to develop applications of portfolio theory for the construction industry. They suggest that using bidding strategy models and portfolio theory allows a contractor to select an optimum mix of construction projects and determine appropriate bid prices. Backlog is one of the factors these writers consider in portfolio design.

Torgersen, Wyskida and Yarbrough (27) developed a bidding-work game that recognizes that the competitive bidding process requires an assessment of work loading requirements and work load capacity. These researchers state that the primary emphasis of competitive bidding strategies is the determination of an optimum bid price, and they maintain that optimum work loading and scheduling of projects within an established capacity is an equally important determination.

3.1.3 The Need for Research

It is noted in this section that several researchers and many contractors feel that the backlog of work is an important variable to consider when developing a business strategy. It would be difficult to support or reject the hypothesis that the backlog of work should

influence the level of markup applied to a cost estimate without considering the primary objective of the company in question. There is little doubt that many contractors in the construction industry do not strive to maximize profits or return on investment. The contractor whose primary business objective is to keep all personnel employed may sacrifice profits and perhaps intentionally assume an unprofitable business strategy to satisfy this objective. When the contractor's backlog of work approaches a level where layoffs may be necessary, his strategy will reflect the need for work to statisfy the company's primary objective: keep everyone on the payroll.

It is not the intent of this thesis to debate business objectives, and it is assumed in this thesis that contractors strive to maximize net profits and use expectancy pricing methods to determine an optimum markup. Should markup be slightly raised or lowered as the backlog of work increases or decreases? If so, when should the contractor modify markup and by how much? Questions such as these reflect the need to determine if the backlog of work should be considered in the development of a formal bidding strategy.

3.2 Project Size and the Backlog of Work

The backlog of work model is a simplification of the process by which projects are won and completed by an enterprise. The model represents a single queue with a queue length in dollars equal to the bonding capacity established by the company's surety. Assume, for example, that a company's current backlog of work is $300,000. The company has just been awarded three contracts bid at $100,000 each.

Figure 3.3 reflects the loading of the work capacity queue to $600,000. If the company desires more work, the project size that may be considered must be bid at $50,000 or less due to bonding constraints. In this situation, project size (estimated or actual cost) would be a factor to consider when determining which project or projects will be bid next.

Assume that a month passes and no projects are bid and that the contractor completes $70,000 of work during the month. Figure 3.4 reflects this change in the backlog of work. The contractor may now consider bidding projects up to $120,000 if the contractor wishes to maintain a backlog that approaches the firm's bonding capacity, and may now be more selective in determining which projects will be bid.

Figure 3.5 shows a situation that is slightly more complex than the two cases presented above. Assume that a contractor's current backlog of work is $300,000 with a bonding limit of $650,000. The contractor is aware of eight projects to be let in the near future: three at $50,000, two at $100,000, two at $200,000 and one at $300,000. The contractor may elect to bid one of the $50,000 projects and the $300,000 project (Case A in Figure 8), or all three $50,000 projects and one $100,000 project (Case B in Figure 8), and so on for any combination of projects less than $350,000. The question facing the contractor is: What project or combination of projects should I bid to maximize my net profits?

For each class of work that a construction company performs, net profits are influenced by the level of markup and costs of estimating and overhead. For the cases presented in Figure 3.5, the contractor may be able to estimate and perform $50,000 and $100,000 projects more

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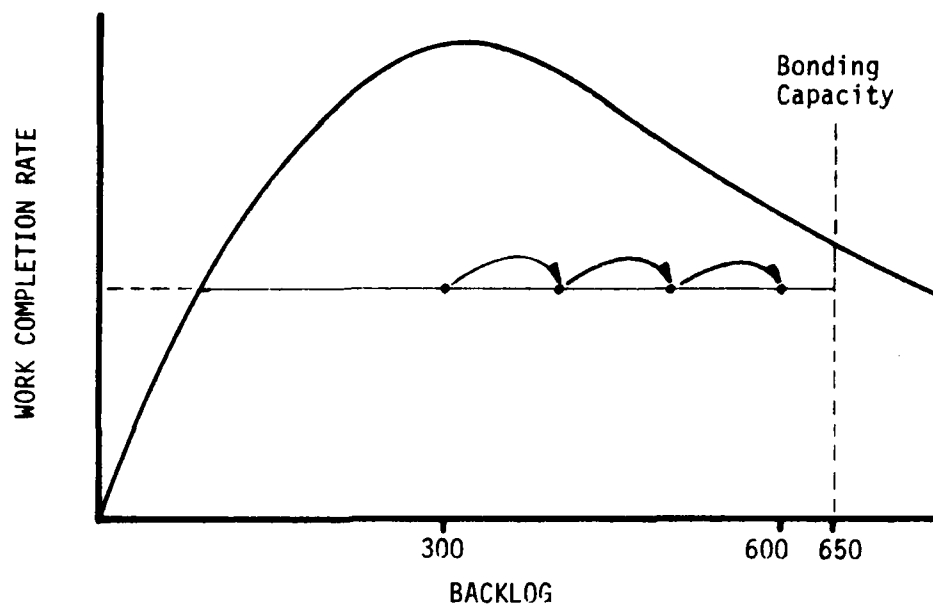
FIGURE 3.3 -- LOADING THE BACKLOG OF WORK
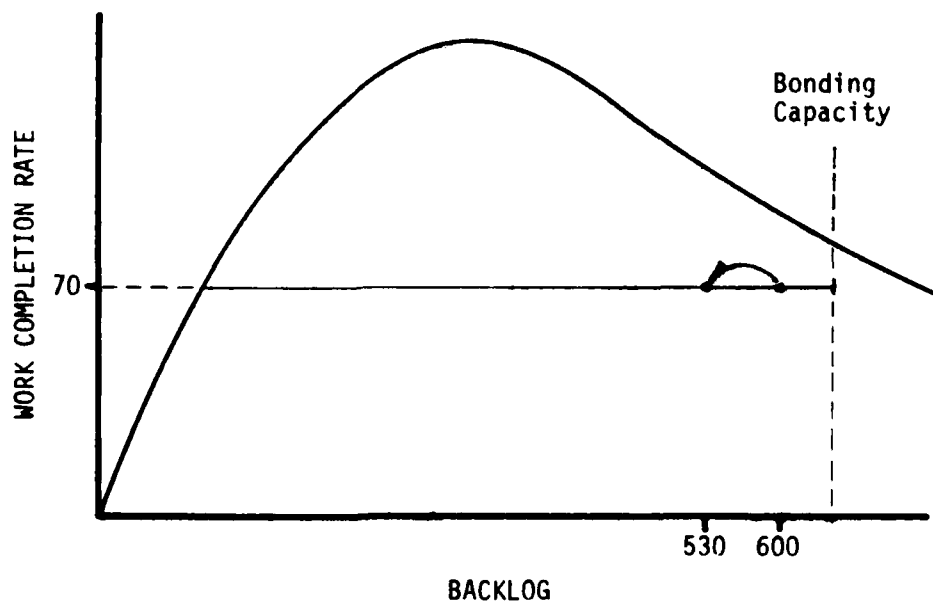
FIGURE 3.4 -- WORKING OUT OF BACKLOG

23
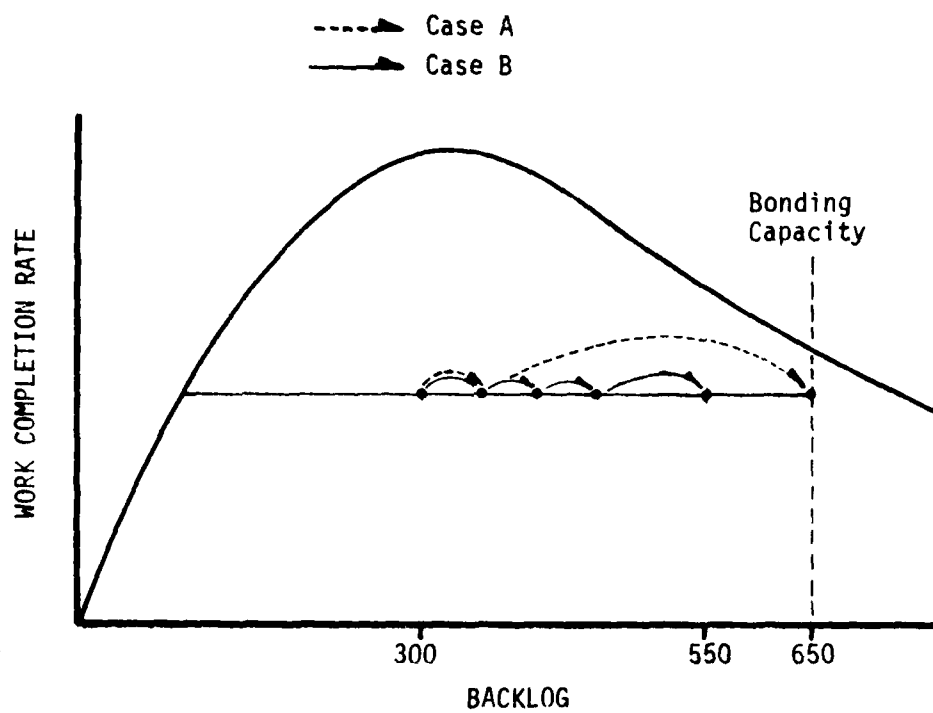
FIGURE 3.5 -- LOADING A COMBINATION OF PROJECT SIZES

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efficiently than the larger jobs. In such a case, the contractor might first bid the smaller jobs before considering the larger jobs.

Construction markets vary greatly with the type of work performed, the level of competition, etc. Markets may exist where the variance of project size is relatively small and contractors competing in these markets need only be efficient over a small range of project sizes to remain competitive. These contractors may never have to decide whether to bid five small projects or one large one. Other markets may exist where a contractor can perform work within a wide variation of project sizes. Within these markets, contractors need to understand the impact that project size may have on the objective of maximizing net profits for a given operation.

3.2.1 Review of the Literature and Current Research

Several researchers have recognized that project size may influence a bidding strategy designed to maximize net profits. The writer shall briefly present only the works of Larew (14) and Grieve (10) since these works represent the state-of-the-art in this area of research.

Larew found in his study of a general contracting firm that optimum markup decreases as project size increases (14:27) and that a minimum project size may be identified based on the costs of estimating and overhead expressed as a function of project size (14:222). At the minimum project size, the maximum expected net income is zero, and the contractor can expect to do no better than breakeven (14:222). The joint response surface of expected profits, shown in Figure 3.6, was developed for the operation studied (14:28), and the surface suggests

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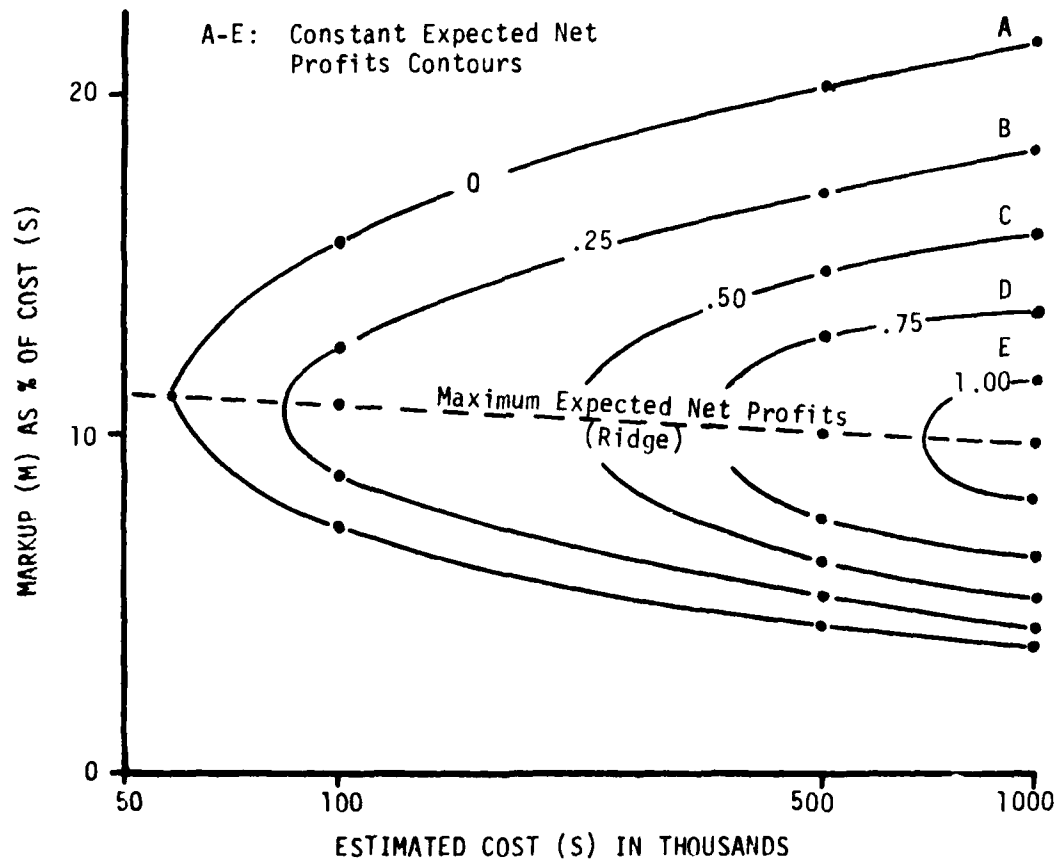
FIGURE 3.6 -- EXPECTED NET PROFITS RESPONSE SURFACE (RIDGE)
(14:28)

that the company should always give priority to estimating and bidding large opportunities.

Grieve has further developed the work of Larew in the area of expected profits response surfaces. Grieve found that the costs of estimating and overhead and the bid/get ratio influence the shape of the response surface. The ratio may be defined as "the average number of dollars (cost) that must be bid to win one dollar (cost) at a given markup" and the ratio is equal to the reciprocal of the probability of winning (14:200). For certain conditions, the response surface may have the shape of a mountain, as shown in Figure 3.7, and an optimum project size may be identified (10). The contractor with this response surface should give priority to estimating and bidding projects as close to this optimum project size as possible to maximize expected net profits in this market.

3.2.2 The Need for Research

The studies of Larew and Grieve suggest that project size is an important variable to consider in the development of a business strategy. It is believed that the backlog of work model may provide additional insight into the influence of project size on net profits. The following scenario is presented to demonstrate how the backlog model may be used in this study. Figure 3.8 shows the backlog of work relationship for a given company operation where $K = 0.002$ and $C = 1.5$. (The reader is reminded that the backlog curve is an expression of the relationship between W and U and that the mean work completion rate is constrained by the availability of working capital for

27
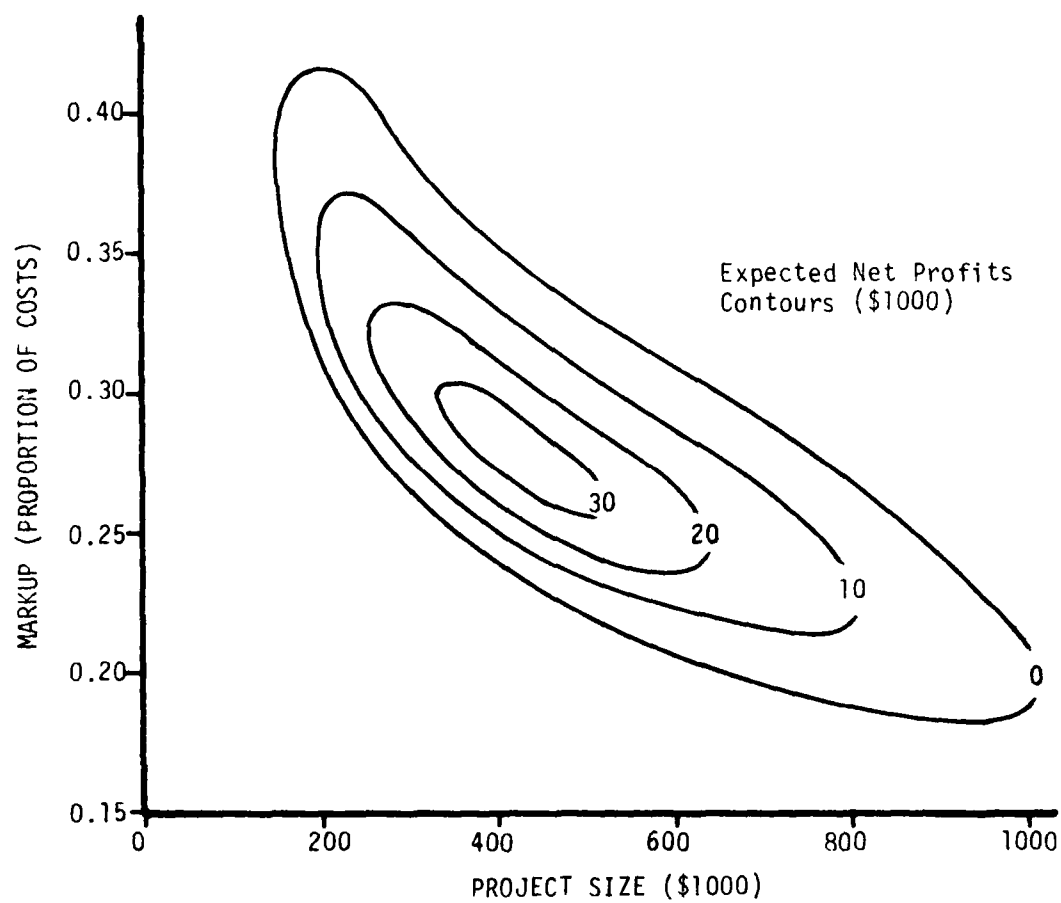
FIGURE 3.7 -- EXPECTED NET PROFITS RESPONSE SURFACE (MOUNTAIN)

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field operations). In Case A, the contractor may operate efficiently over backlogs that range from A' to A" and the work completion rate for this enterprise shall be called "Low." Case B shows the same operation but a greater amount of working capital is available for field operations and the work completion rate is "High." Without changing the backlog of work relationship (information system or personnel factors are constant), the contractor may operate efficiently over backlogs that range for B' to B", but the contractor does not operate efficiently at backlogs from B" to the bonding capacity. Although Case B represents an operation with a higher level of capitalization, the range of backlog for efficient operations has decreased. This suggests that the company's information system and personnel are unable to cope with the increased level of activity at any backlog that exceeds B". It also suggests that project size may become a critical factor to consider in the bidding strategy. Neglecting the constraints imposed by the company's surety on project size, the maximum project size that the company may consider in Case A must be less than the difference between A' and A" and, in Case B, less than the difference between B' and B" if the company wishes to operate efficiently within the constraints imposed by the backlog of work curve. This scenario suggests that the backlog of work model may provide some insight into the impact of project size on net profits when incorporated into a bidding strategy.

3.3 Working Capital and Bonding Capacity

Figure 2.1 previously showed that the backlog of work curve for a given company operation is constrained in all directions. The mean
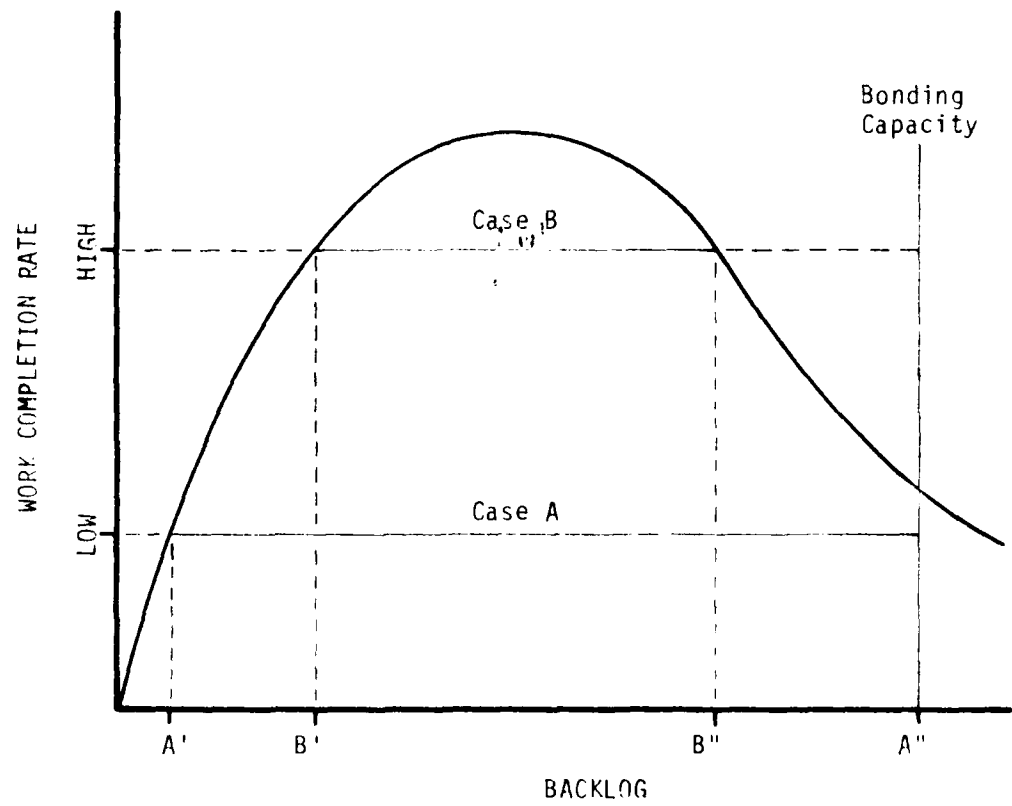
FIGURE 3.8 -- PROJECT SIZE AND THE RANGE OF EFFICIENT OPERATIONS

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work completion rate and the bonding capacity are related to the degree that working capital is a primary determinant of these constraints. The backlog of work model suggests that the construction company's financial makeup is an important consideration in the planning of construction operations.

The apparent mismanagement of financial resources is a major problem in the construction industry today. Table 3.1 outlines the primary reasons for construction company failures and suggests that the lack of working capital is the greatest single cause of failures in the United States (1:310). Antil states that "it is well known that the (most common) cause of financial failure is too much work for the available capital: funds become so widely and thinly spread that a single losing project can mean disaster" (1:222). Bonny and Frein note that "surety statistics indicate that 'overexpansion,' i.e. taking on more work than a contractor's working capital can handle, probably is the major cause of failure in the building field" (5:82). Another related criticism of the construction industry is that contractors are typically undercapitalized (12:165, 28:52). Undercapitalization suggests that "construction firms show (low) ratios of fixed capital to total assets" (28:52) and that suppliers, bankers and sureties extend credit or bonding beyond the worthiness of the organization (12:165, 33:248). These variants of the lack of working capital are presented only to suggest that bankers, suppliers, sureties, owners and other parties in the construction process are partially responsible for low profits and failures in the industry. There is a need to examine working capital management from the perspectives of each of the above parties.

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TABLE 3.1 -- REASONS FOR CONSTRUCTION
COMPANY FAILURES (1:310)

Cause of Failure	Percentage of Total Construction Failures	
	Australia	USA
Lack of working capital	25	33
Low estimating	23	24
Inadequate cost and accounting records	20	21
Managerial inexperience and incompetence	14	20
Reckless trading	9	?
Incompetent site supervision	7	?
Other reasons	2	2
	100	100

3.3.1 The Operating Capital Constraint*

The work completed by an enterprise in any month is limited by a wide variety of factors, such as, the availability of skilled labor, the adequacy of owned or rental equipment, the availability of suitable work and the amount of working capital available to finance construction activities. Discussion in this thesis is limited to financial considerations and the impact of working capital on the backlog of work curve. Working capital may be defined as the "excess of total current assets over total current liabilities" (33:241) and is commonly referred to as the contractor's net quick worth (5:86). Table 3.2 lists current assets and current liabilities that are usually considered when determining a contractor's net quick worth (5:86). If one considers financial structure to be the heart of the construction company, working capital may be considered the beat that is required to "provide for the day-to-day expenditures, such as payroll, purchases, the payment of accrued taxes and expenses, etc." (17:78).

Larew states that the work completed by an enterprise in any month may be limited by the working capital allocated to field operations in accordance with the work completion rate function:

$$W = LO(1 + i_p/i_e)^{-1} \qquad (3.1)$$

where, W = Work completed during the month in thousands of dollars,

i_e = The interval between periodic billings in weeks,

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* Unless otherwise noted, the material in this section is from the work of Larew (14).

TABLE 3.2 -- DETERMINING NET QUICK WORTH
(5:86)

Current Assets	Current Liabilities
Cash available for field operations	All accounts payable due suppliers and subcontractors
Accounts receivable from completed contracts	Full or parital notes payable within one year
Earned estimates on uncompleted contracts, to include retainages	Notes secured by chattel mortgage on equipment
Other valid and collectible accounts receivable	Balance due on equipment within one year
Notes receivable if due within one year	Accrued expenditures for payroll, insurance, employee withholds and the like
Certified checks deposited with bids	Social security and income tax withholds due
Corporate stocks of quality companies	Notes due officers, partners, stockholders or other parties
Municipal and federal bonds	
Value of materials on hand purchased for use on current contracts	
Cash surrender value of life insurance	
Miscellaneous investment assets	

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i_p = The interval between the date of the billing and payment thereof in weeks,

O = Working capital allocated to field operations in thousands of dollars (operating capital), and,

L = Working capital leverage.

The distinction between operating capital, O, and working capital is an important one, and the ratio of operating capital to working capital* may provide some insight into the financial health of an enterprise. This ratio will range from 0 to 1, but, since the ratio is not discussed in the literature, a general rule of thumb for favorable ratios does not exist. The favorable ranges of other financial ratios (33:241) and the recognized need to maintain a high level of liquidity (17:78) suggest that a favorable ratio of operating capital to working capital would range between, say, 0.8 to 1 and 1 to 1. One may consider this ratio as a measure of liquidity. The most common measure of liquidity is the Acid Test: cash and receivables divided by current liabilities. The contractor's banker and surety normally consider a ratio of at least 1 to 1 to indicate a healthy financial position (33:241). The primary drawback of the Acid Test is that the test implicitly assumes that liquid assets will be used to support field activities; therefore, the operating to working capital ratio may be more indicative of the company's actual financial stability. Improvement of this ratio is one way to increase the mean monthly work completion rate. The contractor with an operating to working capital ratio of, say, 0.2 to 1 has

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*The operating capital to working capital ratio is not a common financial ratio. The common financial ratios that a banker or surety will examine may be found in references 17 and 33.

relatively little capital available to finance field activities. A poor ratio such as this may be the result of many financial ailments: failure to collect receivables when due, an overstocked inventory, a poor credit rating (unable to borrow against short-term or long-term assets), etc. Each of these ailments would reduce the liquidity of working capital and lower the amount of capital available for field operations. A poor credit rating takes on particularly significant importance in the construction environment: the contractor suffering from a poor credit rating is facing failure because credit is the financial foundation of the entire construction industry (33:237).

Improvement of the operating to working capital ratio is only one method of increasing the mean work completion rate, W. The parameter i_p may be improved (decreased) by obtaining a faster turnover in receivables and inventories, and the parameter i_e may be improved (increased) by extending payment of current liabilities. Leverage may be improved by subcontracting work at a cost less than could be performed by in-house forces or adding a markup to billings that exceeds the retained percentage. Leverage is decreased, for example, when the owner does not pay for prepaid insurance, bonds, delivered materials and preparatory work. The reader may note that strategies aimed at improving one variable in the work completion rate function are overlapping and a change of modus operandi may improve one or several variables. The strategies employed by the contractor to improve the operating to working capital ratio, leverage, i_p and i_e are presented only to introduce the reader to the work completion rate function and are outside the scope of this thesis. The work completion

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rate function is important because it establishes the mean work comple-
tion rate that constrains the backlog of work curve. The operating to
working capital ratio and all other commonly used financial ratios pro-
vide insight into the financial stability of a construction enterprise.
It is emphasized, however, that these ratios provide, at best, rules of
thumb, and the unique character of the individual construction company
will determine the relative degree of financial success that the com-
pany will enjoy.

3.3.2 The Bonding Constraint

Benjamin noted in his research and development of a competitive
bidding strategy that, while he did not consider it, a contractor's
bonding capacity is an important constraint to consider in the total
business strategy (3:92). Bonding capacity "refers to the maximum
value of uncompleted work that the surety will allow the contractor to
undertake at any one time" (7:125). Not all construction contracts re-
quire a surety or performance bond equivalent to 100% of the contract
amount, but there is a growing tendency for owners to specify that the
general contractor must be fully bonded (6:83). The bonding concept in
construction evolved from the owner's desire to minimize risk when
awarding contracts. By requiring a performance bond, the owner per-
forms a preliminary screening of contractors that will be permitted to
bid the work (6:83). The contractor who is unable to obtain a bond
from a surety company may be classified by the owner as a poor risk and
is eliminated from consideration for a contract. The bond also pro-
vides the owner with "an insurance policy . . . that guarantees that

(the) project will be completed for the bid price and no more, excluding change orders or additional work" (6:83). A common belief is that bonding requirements serve primarily the owner and that the construction contractor receives very little from this requirement (6:68). On the surface, this may seem true, but bonding requirements serve the contractor by constraining his backlog of work to a limit that is considered within his financial capability. There is little doubt that there is a limit to "the number of jobs which car be estimated, obtained and properly handled" (29:63) by any contractor.

The primary reason for examining bonding in this thesis is to explore how a bonding limit is or should be established by the surety and not for what bonding accomplishes. Table 3.3 outlines items that the surety will examine when setting a contractor's bonding capacity. While all of these factors are important, the principal gauge that will determine the bonding capacity allowed by the surety is the contractor's working capital (5:85). Bonding capacity is normally expressed as an integer times working capital, and, depending on the reference, surety, state, type or work, etc., bonding capacity usually ranges from 10 to 20 times the working capital (7:125). Using this simplified rule of establishing the bonding capacity solely by the working capital, the bonding constraint may easily be incorporated in modeling with the backlog of work curve. Figure 3.9 shows a typical backlog of work curve to include a working capital axis and iso-bonding lines. The scales for the work completion rate and working capital are determined by the work completion rate function. These scales will be identical if, for example, operating capital is equivalent to working capital, leverage equals

TABLE 3.3 -- DETERMINANTS OF BONDING CAPACITY

Determinants of Bonding Capacity
Complete balanced financial statement
Company organization and history
Qualifications and experience of key personnel
Type and success of past work
Inventory of equipment
Inventory of materials (19:28-7)
Uncompleted work on hand -- bonded and unbonded, including work bid but not yet awarded
Availability of credit
Spread between contractor's winning bid and the next lowest bidder
Contract size -- normally maximum size to be limited to one half of the bonding capacity
Terms of payment specified in contract
Amount of work subcontracted and qualifications and bonding of subcontractors (7:124)
Other conditions in the specific contract for which bond is requested (6:92)
Adequacy of accounting system (5:85)
Amount of working capital (5:86, 7:124)
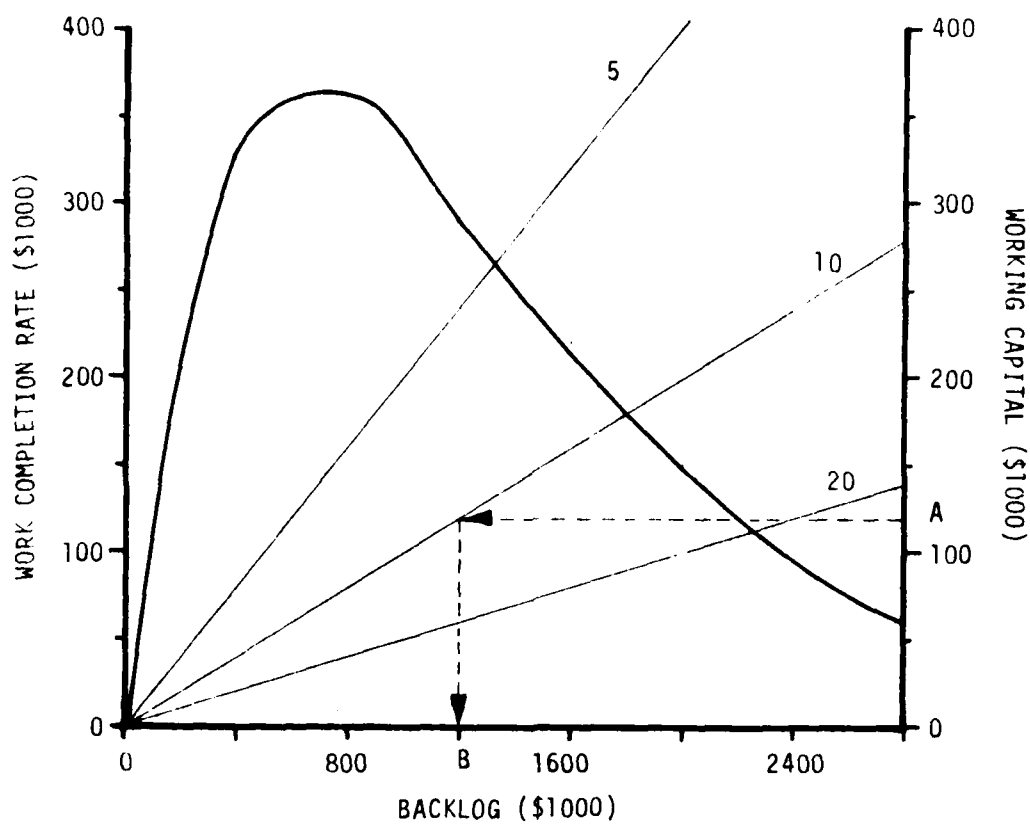
FIGURE 3.9 -- WORKING CAPITAL AND ISO-BONDING LINES

1.5, i_e equals 4 weeks and i_p equals 2 weeks. Iso-bonding lines are established by dividing levels of the backlog of work by the rate at which bonding capacity is set by the working capital. Figure 3.9 shows a working capital level (point A) and the corresponding bonding capacity (point B) using the iso-bonding line where bonding is set at 10 times working capital.

3.3.3 The Need for Research

The introductory discussions of the mean work completion rate and bonding constraints are presented to aid the reader in understanding how the backlog of work model may be used to explore the concepts of capitalization and bonding capacity. It would of course be desirable to know what level of capitalization best allows a contractor to maximize profits for a given operation in a given class of work. Figure 3.10 shows a backlog of work curve with three levels of the mean work completion rate: HIGH, MEDIUM and LOW. If it is assumed for the relationship, $W = LO(1 + i_p/i_e)^{-1}$, that leverage equals 1.5, operating capital equals working capital, i_p equals 2 weeks and i_e equals 4 weeks, then the work completed each month is equivalent to the level of working capital, and the bonding capacity is set, for example, at 10 times the work completion rate. Figure 3.10 immediately gives rise to two questions. First, what level of capitalization is optimal for this operation? Second, what is the appropriate bonding capacity with respect to any given level of capitalization?

In Figure 3.10 it appears that the contractor is overcapitalized at the HIGH level because operations become inefficient at backlogs ex-

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ceeding point H. The bonding capacity for this level (HBC) is set by the 10-times iso-bonding line. At the LOW level, the contractor is relatively unaffected by the backlog of work curve and operates efficiently at backlogs up to the established bonding capacity. The contractor in this case has the potential to increase capitalization without incurring inefficiencies in the work completion rate, and one may consider the contractor to be undercapitalized* at this point. There must exist some level between HIGH and LOW that is optimum for the given company operation. The MEDIUM level is presented in Figure 3.10 to suggest that this optimum level of capitalization exists somewhere close to the intersection of the backlog of work curve and the iso-bonding line.

The above discussion also touches on the second question. It would initially appear that the bonding capacity at the HIGH level has not considered the contractor's inefficiency at high levels of backlog and has been improperly set. The contractor could not remain at this level of capitalization without unlimited financial resources unless constraint is exercised from exceeding backlogs around point H. Since virtually no contractor has unlimited funding, the contractor must exercise constraint in bidding work or divert capital for the improvement of the information system or for the hiring of additional supervisory personnel, i.e. improve the backlog of work curve. If action is not taken to avoid inefficiency at high levels of backlog, the level of capitalization will drop as costs exceed estimates (assuming true cost equal

*The terms "overcapitalized" and "undercapitalized" are used here to denote levels of capitalization relative to some optimum level. These terms are not congruent with levels of capitalization with respect to the potential work completion rate as described by the backlog of work curve.
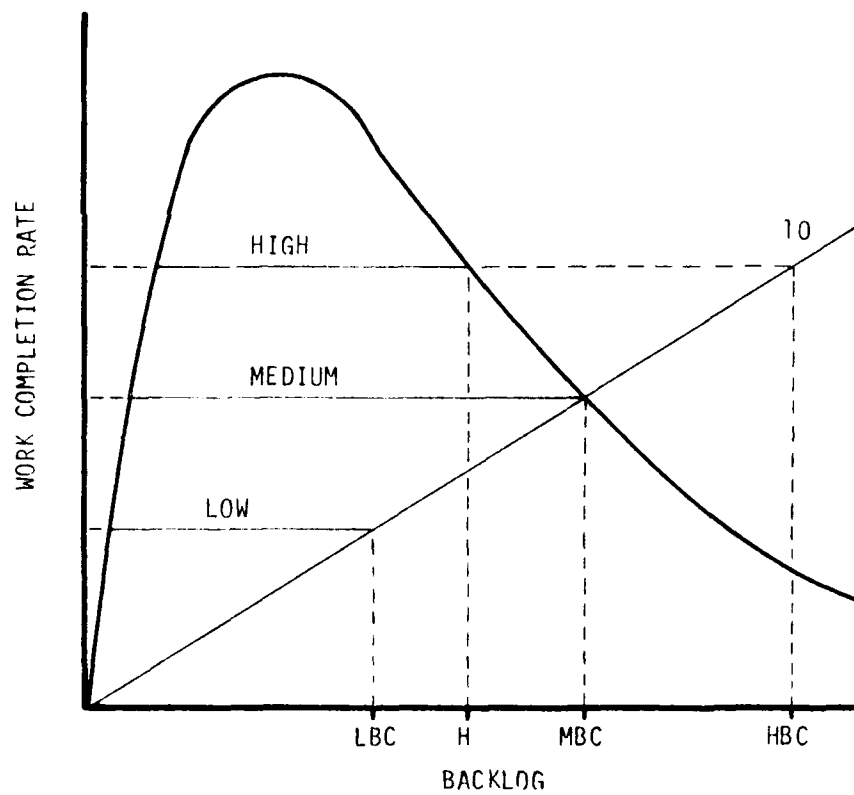
FIGURE 3.10 -- LEVELS OF CAPITALIZATION AND BONDING CAPACITY

estimated costs).

The above examples show that there is a need to examine financial strategies and bonding capacity by modeling with the backlog of work curve. The insight gained from such modeling may be beneficial to contractors, sureties, bankers and owners.

3.4 Summary

The construction industry will face many challanges in the near future and the ability of industry personnel and researchers to confront these challenges will have a great impact on the survivability of the individual construction enterprise and the stability of the United States economy. There is a recognized need to develop management techniques particularly suited for a complex and somewhat unique industry. Any technique or model that may provide insight to the mechanics of the individual firm or industry practices, regardless of the degree of simplicity, creates the potential for improved operations, lower failures, higher profits and a generally healthier industry.

The backlog of work model presents a fresh approach for examining important issues in the construction industry. This model appears to be adaptable to a wide range of studies: the impact of the backlog of work on a competitive bidding strategy, the impact of project size on profitability, and optimum capitalization and bonding capacity. Little or no research effort has been expended on the above topics and research that has been accomplished is superficial at best, with the exception of current research on project size. The next chapter outlines the experiments performed by the writer to examine each of the above issues.

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CHAPTER 4

EXPERIMENTS WITH THE BACKLOG MODEL

The purpose of this chapter is to introduce the reader to the re-
search methodology and experiments performed by the writer. The first
two sections briefly discuss the computer programs used during the
course of research: BACKLOG, MAG, and N-BIDDER. The third section
summarizes the assumptions that are applicable to all experiments. The
fourth section summarizes insight gained from initial experimentation
and outlines the order in which experiments and studies are performed.
The last three sections discuss the purpose of each experiment and in-
puts for the BACKLOG program.

4.1 The BACKLOG Program

The BACKLOG program was developed by the writer to perform all
necessary experimentation. The program allows the user to compare two
competitive bidding policies over some specified length of time.
The primary basis for comparison in this thesis is total net profits at
the end of the specified length of time; however, other bases may be
developed and utilized. The first bidding policy, the M* bidding policy
developed by Larew (14), does not account for variations in the work
completion rate with respect to variations in the backlog of work.
While the relationship between the work completion rate and the backlog

of work applies, the contractor is unaware of this relationship. This concept is presented in Figures 4.1 and 4.2. The wide horizontal line in Figure 4.1 shows the assumed work completion rate for the M* bidding policy for a specific level of capitalization. Figure 4.2 shows the actual work completion rate for the operation regardless of the bidding policy employed. All bidding strategies presented in the literature that are applicable to the construction environment do not account for such variables as the work completion rate, the backlog of work, the level of capitalization, etc. The second bidding policy, the M** bidding policy, modifies the M* policy in some manner specified by the user. These two bidding strategies are briefly discussed in Appendix A. Documentation for the BACKLOG program is presented in Appendices B, C, and D. Sample computer runs are presented in Appendix G.

4.2 N-BIDDER and MAG Computer Programs

Prior to using the BACKLOG program, it is necessary to establish all user specified information. The inputs required for the program are outlined in Appendix B, and they may be determined through analysis of actual market conditions or they may be contrived. All of the inputs for experiments in this thesis are contrived, but they are representative of construction data studied at The Ohio State University. Two computer programs are used to determine some of the inputs for the BACKLOG program: N-BIDDER and MAG.

N-BIDDER is a robust computer simulation program that was developed by Frost (9) for the sophisticated simulation of competitive bidding environments. The N-BIDDER program is used in this thesis to generate a

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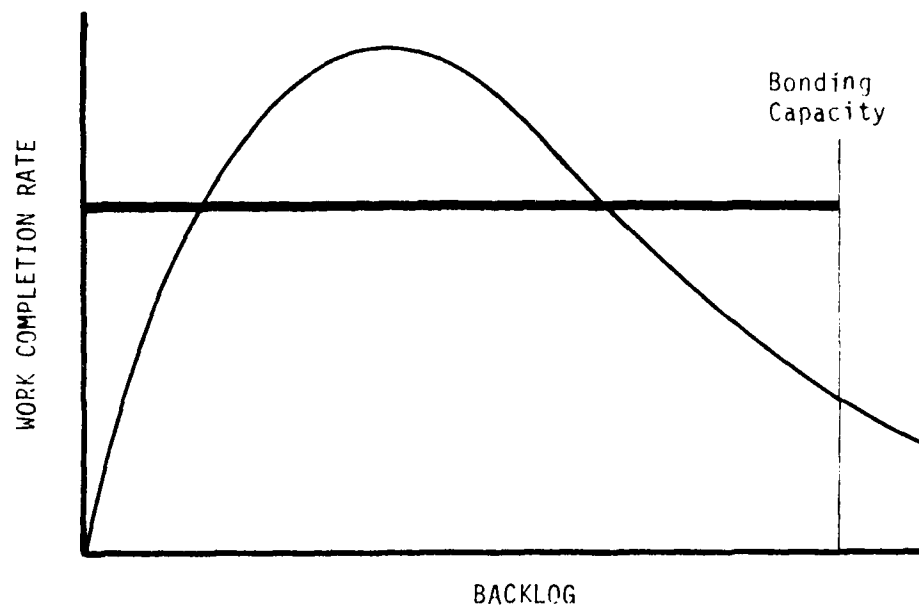
FIGURE 4.1 -- ASSUMED WORK COMPLETION USING M*
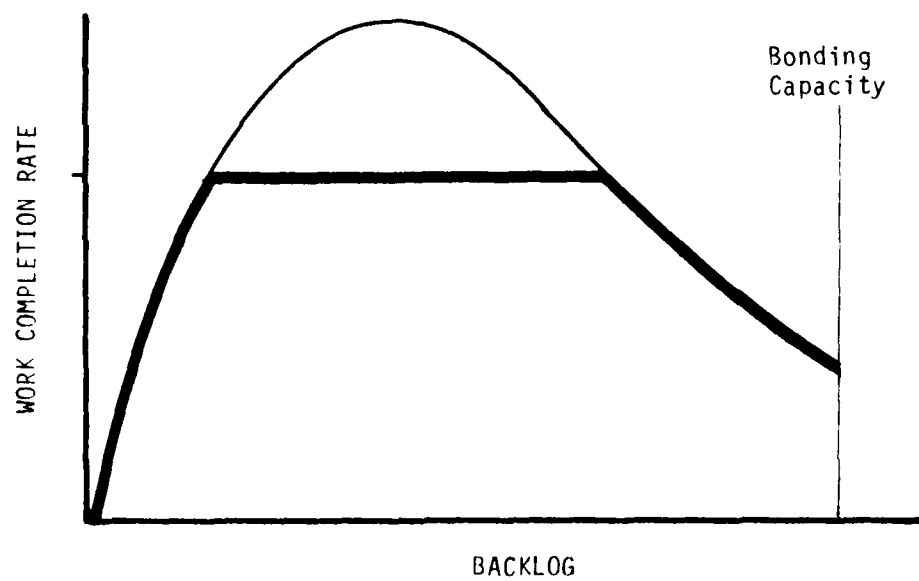
FIGURE 4.2 -- ACTUAL WORK COMPLETION RATE REGARDLESS OF BIDDING
POLICY

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base of past data which consists of a contractor's cost estimate and the perceived markup of the winning bid for each project in a competitive market. This data is analyzed using the MAG (Models and Goodness-of-Fit) program that was developed by Ludolph (18), to include the MAIN3* subroutine required to determine the contractor's M* bidding policy. Recent modifications to the MAIN3 subroutine by Grieve (10) allow the user to specify functions for the costs of estimating and overhead that are used in determining M* and expected net profits. MAG provides two equations that are required to simulate a competitive market environment. First, the contractor's perception of the low bidder's pricing strategy is established. The equation representing this perception contains both deterministic and random variable terms and is of the form, $M = A + CX^K + R(p)$. Second, using this perception and assuming that the low bidder will behave in the future as he has in the past, an M* bidding policy is established based on the objective of maximizing expected net profits. The equation representing this policy contains only deterministic terms and is of the form $M^* = A + CX^K$. These two equations are important inputs required by the BACKLOG program, especially if two competitive bidding policies are to be compared on the basis of net profits.

4.3 Primary Assumptions

The BACKLOG program represents an initial attempt to integrate the backlog of work model into the total construction company environment. Due to both internal and external factors, this environment is

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*MAIN3 is not included in reference 18.

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extremely complex, and a great number of assumptions must be made to permit modeling at even a moderate level of sophistication. Unless otherwise noted, the following assumptions are applicable to all experiments in this thesis:

1. The monthly work completion rate is not a random variable, as shown in Figure 2.1, and the mean monthly work completion rate is adequate for initial modeling and simulation. This assumption is made for two reasons. First, it is believed that the backlog of work model may be more readily studied with a deterministic work completion rate. Second, typical distributions of the work completion rate are not known due to the lack of actual construction data.

2. The contractor's modus operandi remains unchanged during the specified time period for each experiment. This means, for example, that no additional equipment will be rented and that the labor force does not change as the backlog of work changes.

3. The estimated labor and equipment operating costs constitute 50% of the total estimated project cost. This proportion is used to determine the additional costs that the contactor assumes if operations become inefficient due to the constraints of the backlog of work curve.

4. Projects that are bid and won are immediately loaded into the contractor's backlog of work. Since the BACKLOG program does not employ a time calendar, one may perceive that all projects are bid, won and started on the first day of each month. This assumption is made to simplify the BACKLOG program for the initial experimentation performed in this thesis.

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5. The contractor performs work equally on all projects in the backlog queue.

6. The estimated cost of a project equals the true cost if inefficient operations do not occur at high or low backlogs of work due to constraints of the backlog of work curve.

7. All experiments in this thesis are run for a single market environment. The contractor's M* bid/get ratio is approximately equal to 3. The same functions for the contractor's M* markup, the competitor's markup, the cost of estimating and the cost of overhead are used in all experiments.

8. The market contains sufficient bidding opportunities to allow the contractor to bid projects any time the backlog of work is less than the bonding capacity.

9. The contractor's only objective is to maximize net profits.

10. The mean work completion rate is a measure of the level of capitalization, and these terms may be interchangeably used throughout this thesis. The work completion rate function is assumed to be, $W = (1.5)0(1 + 2/4)^{-1} = 0$; therefore, the mean work completion rate, W, is equivalent to the operating capital available for field operations, 0. Furthermore, it is assumed that working capital and operating capital are equal. These assumptions are made primarily because, to the writer's knowledge, no research has been accomplished that examines in detail leverage in the construction environment or that distinguishes between operating and working capital. The literature suggests that a highly liquid financial position is desirable in the construction environment and that liquid assets are used primarily for financing field

operations. Thus, the assumption that operating capital equals working capital seems to be one that at least bankers and sureties would desire.

11. Bonding capacity is established at a rate of 10 times the mean work completion rate. It is also assumed that the contractor's surety is satisfied with other company and environmental factors that may influence the bonding capacity.

12. All results are for the M* bidding policy only.

13. The contractor's estimating capacity is not a limiting company variable. It is assumed that, if required, the contractor may hire qualified estimating personnel in the local labor market.

4.4 Initial Experimentation

Initial experiments using the BACKLOG program suggested that the three areas of study outlined in Chapter 3 should be addressed in the following order:

1. WORKING CAPITAL AND BONDING CAPACITY - Can the model be used to explore organizational financial design? Does an optimum level of capitalization exist for an operation with a predetermined bonding capacity? Does an optimum level of capitalization exist for an operation where bonding varies with the level of capitalization? Can the model be used to determine what proportion of working capital should be budgeted to field operations?

2. PROJECT SIZE - Can the model be used to explore the impact of project size on company net profits? Does a maximum project size exist for a given operation and level of capitalization?

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3. COMPETITIVE BIDDING - Should the optimum markup for any given project size be modified to account for the current backlog of work? If so, when should markup be modified and by how much?

4.5 Experiments with the Level of Capitalization and Bonding Capacity

The primary purpose of the first block of experiments is to explore the impact of the level of capitalization on company net profits. Because bonding capacity is highly related to the level of capitalization, a secondary, but important, purpose is to gain insight into how the backlog of work model may be used to study the bonding capacity.

The first set of experiments in this block is designed to explore the impact of the level of capitalization on a given company operation with a predetermined bonding capacity. Line 2320 in the BACKLOG program (see Appendix C) must be changed for each experiment to reflect the desired bonding capacity for the operation studied. Only the level of capitalization (the variable WMAX in the BACKLOG program) is varied in each experiment. The inputs for the BACKLOG program for these experiments are outlined in Table 4.1, and the results are reported in Section 5.1.1.

The second set of experiments in this block is designed to explore the impact of the level of capitalization on a given company operation with the bonding capacity established at 10 times the level of capitalization. Experiments are run for 16 separate company operations: the parameters K and C in the backlog model are each varied at 4 levels. The inputs for the BACKLOG program for these experiments are outlined in Table 4.2 and the results are reported in Section 5.1.2.

Variable	Value	Variable	Value
NEXPMT	1	DIST(4,6)	0
NSAMPL	12	DIST(4,7)	0
NMONTH	61	DIST(5,1)	0
MINJS	0.5000E+01	DIST(5,2)	0.3000E+00
MAXJS	0.7000E+03	DIST(5,3)	0.7406E+00
LABEQP	0.5000E+00	DIST(5,4)	0
DIST(1,1)	0	DIST(5,5)	0
DIST(1,2)	0	DIST(5,6)	0
DIST(1,3)	0	DIST(5,7)	0
DIST(1,4)	0.3500E+02	DIST(6,1)	0.9944E-01
DIST(1,5)	0.8333E+01	DIST(6,2)	0.6601E+00
DIST(1,6)	0	DIST(6,3)	-.3612E+00
DIST(1,7)	0.1800E+01	DIST(6,4)	0
DIST(2,1)	0	DIST(6,5)	0.5415E-01
DIST(2,2)	0	DIST(6,6)	0.2000E+00
DIST(2,3)	0	DIST(6,7)	0.2600E+01
DIST(2,4)	0.1000E+03	PRNOP1	0
DIST(2,5)	0.1681E+04	PRNOP2	0
DIST(2,6)	-.4500E+00	EXOPT1	1
DIST(2,7)	0.3200E+01	EXOPT2	0
DIST(3,1)	0.2287E+00	ISEED1	22092503
DIST(3,2)	0.4246E+00	ISEED2	897712097
DIST(3,3)	-.3167E+00	ISEED4	1417473372
DIST(3,4)	0	ISEED5	553645566
DIST(3,5)	0	ISEED6	755319619
DIST(3,6)	0	RATBC	0
DIST(3,7)	0	RATMMA	1000.0
DIST(4,1)	0	RATMMB	-.0001
DIST(4,2)	0.1500E+00	KB	0.1500E-02
DIST(4,3)	0.3750E+00	CB	0.1500E+01
DIST(4,4)	0	WMAX	Varies
DIST(4,5)	0	OPTJS	0.1000E+03

COMMENTS: Experiments are run for bonding capacities of
1600, 1800, 2000, 2200, and 2400 (in thousands of dollars).
WMAX was changed for each sample in each experiment as outlined
below:
If BONDCP=2400. then WMAX=50,60,70,80,90,100,120,130,140.
If BONDCP=2200. then WMAX=120,130, . . . ,210,220.
If BONDCP=2000. then WMAX=120,130, . . . ,210,220.
If BONDCP=1800. then WMAX=170,180, . . . ,260,270.
If BONDCP=1600. then WMAX=200,210, . . . ,300,320.

TABLE 4.2 -- BACKLOG INPUTS FOR VARIABLE BONDING
CAPACITY EXPERIMENTS

Variable	Value	Variable	Value
NEXPMT	1	DIST(4,6)	0
NSAMPL	12	DIST(4,7)	0
NMONTH	61	DIST(5,1)	0
MINJS	0.5000E+01	DIST(5,2)	0.3000E+00
MAXJS	0.7000E+03	DIST(5,3)	0.7406E+00
LABEQP	0.5000E+00	DIST(5,4)	0
DIST(1,1)	0	DIST(5,5)	0
DIST(1,2)	0	DIST(5,6)	0
DIST(1,3)	0	DIST(5,7)	0
DIST(1,4)	0.3500E+02	DIST(6,1)	0.9944E-01
DIST(1,5)	0.8333E+01	DIST(6,2)	0.6601E+00
DIST(1,6)	0	DIST(6,3)	-.3612E+00
DIST(1,7)	0.1800E+01	DIST(6,4)	0
DIST(2,1)	0	DIST(6,5)	0.5415E-01
DIST(2,2)	0	DIST(6,6)	0.2000E+00
DIST(2,3)	0	DIST(6,7)	0.2600E+01
DIST(2,4)	0.1000E+03	PRONOP1	0
DIST(2,5)	0.1681E+04	PRNOP2	0
DIST(2,6)	-.4500E+00	EXOPT1	1
DIST(2,7)	0.3200E+01	EXOPT2	0
DIST(3,1)	0.2287E+00	ISEED1	22092503
IDST(3,2)	0.4246E+00	ISEED2	897712097
DIST(3,3)	-.3167E+00	ISEED4	1417473372
DIST(3,4)	0	ISEED5	553645566
DIST(3,5)	0	ISEED6	755319619
DIST(3,6)	0	RATBC	10.0
DIST(3,7)	0	RATMMA	1000.0
DIST(4,1)	0	RATMMB	-.0001
DIST(4,2)	0.1500E+00	KB	Varies
DIST(4,3)	0.3750E+00	CB	Varies
DIST(4,4)	0	WMAX	Varies
DIST(4,5)	0	OPTJS	0.1000E+03

COMMENTS: Experiments are run for 4 levels of KB (.0015,
.002, .003, and .004) and 4 levels of CB (.5, 1.0, 1.5, and
2.0). WMAX is varied for each experiment at 7 to 12 levels.
For example, for the operation with K=.002 and C=.5, 9
samples are run with WMAX=40,50, . . . ,110,120.

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Section 5.1.3 reports the results of a study of the impact of changes of modus operandi and the level of capitalization. This study is based on the findings from the above experiments and examines an actual company operation that has undergone changes in modus operandi and the level of capitalization. The BACKLOG program is not used in this study.

The last area of study in Section 5.1 examines the relationship between working capital and operating capital with respect to the level of capitalization and the bonding capacity for a given operation. It is hoped that some insight may be gained into this relationship by studying the backlog of work model. The results of this study are reported in Section 5.1.4.

4.6 Experiments with Project Size

The primary purpose of this second block of experiments is to explore the impact of project size on company net profits. The first set of experiments is designed to identify a maximum project size that a company should bid to maximize net profits for a given operation. The concept of a maximum project size evolved from initial discussions with Larew and graduate students and from the writer's preliminary study of the backlog of work model. It is believed that a maximum project size must be equal to or less than the range of backlog for efficient operations for a given operation (measured by the variable MAXPRO in the BACKLOG program). To determine this project size for a given operation, the project size to be bid is varied at a given level of capitalization, and the contractor is not permitted to bid work that would result in

inefficient operations at high levels of backlog. The inputs for the BACKLOG program for these experiments are outlined in Table 4.3, and the results are reported in Section 5.2.1.

The second set of experiments in this block is designed to determine the impact of project size on net profits at and around the optimum level of capitalization. Project size is varied in each experiment, and 9 separate operations with 4 levels of capitalization are studied. The inputs for the BACKLOG program for these experiments are outlined in Table 4.4 and the results are reported in Section 5.2.2.

The last area of study in this block attempts to integrate the concepts of Larew and Grieve and the results from the above experiments. It is hoped that some additional insight may be gained by examining the impact of project size on net profits over the entire spectrum of project sizes available for bidding consideration. The results of this study are presented in Section 5.2.3.

4.7 Experiments with Markup**

The primary purpose of this last block of experiments is to determine if the optimum markup (M*) can be improved by modeling with the BACKLOG program. A single operation (K = 0.002 and C = 1.5) is studied at a level of capitalization slightly below the optimum level identified in Section 5.1.2. The project size for all bid opportunities is held constant ($100,000) for all experiments at a level exceeding the modulus

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**The scope of experiments in this section was modified as presented in Section 4.4 due to a problem encountered while trying to determine if markup should be modified with respect to the backlog of work. The results of these preliminary experiments led to the findings reported in Section 5.3.

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TABLE 4.3 -- BACKLOG INPUTS FOR MAXIMUM PROJECT SIZE EXPERIMENTS

Variable	Value	Variable	Value
NEXPMT	1	DIST(4,6)	0
NSAMPL	9	DIST(4,7)	0
NMONTH	61	DIST(5,1)	0
MINJS	0.5000E+01	DIST(5,2)	0.3000E+00
MAXJS	0.1200E+04	DIST(5,3)	0.7406E+00
LABEQP	0.5000E+00	DIST(5,4)	0
DIST(1,1)	0	DIST(5,5)	0
DIST(1,2)	0	DIST(5,6)	0
DIST(1,3)	0	DIST(5,7)	0
DIST(1,4)	0.3500E+02	DIST(6,1)	0.9944E-01
DIST(1,5)	0.8333E+01	DIST(6,2)	0.6601E+00
DIST(1,6)	0	DIST(6,3)	-.3612E+00
DIST(1,7)	0.1800E+01	DIST(6,4)	0
DIST(2,1)	0	DIST(6,5)	0.5415E-01
DIST(2,2)	0	DIST(6,6)	0.2000E+00
DIST(2,3)	0	DIST(6,7)	0.2600E+01
DIST(2,4)	0.1000E+03	PRNOP1	0
DIST(2,5)	0.1681E+04	PRNOP2	0
DIST(2,6)	-.4500E+00	EXOPT1	1
DIST(2,7)	0.3200E+01	EXOPT2	0
DIST(3,1)	0.2287E+00	ISEED1	22092503
DIST(3,2)	0.4246E+00	ISEED2	897712097
DIST(3,3)	-.3167E+00	ISEED4	1417473372
DOST(3,4)	0	ISEED5	553645566
DIST(3,5)	0	ISEED6	755319619
CIST(3,6)	0	RATBC	10.0
DIST(3,7)	0	RATMMA	1000.0
DIST(4,1)	0	RATMMB	-.0001
DIST(4,2)	0.1500E+00	KB	0.2000E-02
DIST(4,3)	0.3750E+00	CB	0.1000E+01
DIST(4,4)	0	WMAX	Varies
DIST(4,5)	0	OPTJS	Varies

COMMENTS: Experiments are run for 5 levels of WMAX (40, 80, 120, 160, and 180). For each experiment, 9 samples are run with OPTJS=50, 100, 200, 300, 400, 600, 800, 1,000, and 1,200.

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TABLE 4.4 -- BACKLOG INPUTS FOR NET PROFITS VERSUS
PROJECT SIZE EXPERIMENTS

Variable	Value	Variable	Value
NEXPMT	1	DIST(4.6)	0
NSAMPL	12	DIST(4.7)	0
NMONTH	61	DIST(5.1)	0
MINJS	0.5000E+01	DIST(5.2)	0.3000E+00
MAXJS	0.7000E+03	DIST(5.3)	0.7406E+00
LABEQP	0.5000E+00	DIST(5.4)	0
DIST(1.1)	0	DIST(5.5)	0
DIST(1.2)	0	DIST(5.6)	0
DIST(1.3)	0	DIST(5.7)	0
DIST(1.4)	0.3500E+02	DIST(6.1)	0.9944E-01
DIST(1.5)	0.8333E+01	DIST(6.2)	0.6601E+00
DIST(1.6)	0	DIST(6.3)	-.3612E+00
DIST(1.7)	0.1800E+01	DIST(6.4)	0
DIST(2.1)	0	DIST(6.5)	0.5415E-01
DIST(2.2)	0	DIST(6.6)	0.2000E+00
DIST(2.3)	0	DIST(6.7)	0.2600E+01
DIST(2.4)	0.1000E+03	PRNOP1	0
DIST(2.5)	0.1681E+04	PRNOP2	0
DIST(2.6)	-.4500E+00	EXOPT1	1
DIST(2.7)	0.3200E+01	EXOPT2	0
DIST(3.1)	0.2287E+00	ISEED1	22092503
DIST(3.2)	0.4246E+00	ISEED2	897712097
DIST(3.3)	-.3167E+00	ISEED4	1417473372
DIST(3.4)	0	ISEED5	553645566
DIST(3.5)	0	ISEED6	755319619
DIST(3.6)	0	RATBC	10.0
DIST(3.7)	0	RATMMA	1000.0
DIST(4.1)	0	RATMMB	-.0001
DIST(4.2)	0.1500E+00	KB	Varies
DIST(4.3)	0.3750E+00	CB	Varies
DIST(4.4)	0	WMAX	Varies
DIST(4.5)	0	OPTJS	Varies

COMMENTS: Experiments are run for 9 seperate operations
(KB=.002, .003, and .004 and CB=.5, 1.0, and 1.5) at 4
levels of WMAX each. For each experiment, 12 samples are
run with OPTJS varying (10, 15, 20, 25, 50, 100, 200, 300,
400, 500, 600, and 700).

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of project size (see Section 5.2).   Two markets are studied in the experiments and the cost of estimating is varied in one market.   The M* markup is increased in increments for each set of runs by changing the parameter A in the subject contractor's M* equation.   The inputs for the BACKLOG program are outlined in Tables 4.5 and 4.6 and the results of the experiments are reported in Section 5.3.

TABLE 4.5 -- BACKLOG INPUTS FOR MARKUP EXPERIMENTS, MARKET C

Variable	Value	Variable	Value
NEXPMT	1	DIST(4,6)	0
NSAMPL	1	DIST(4,7)	0
NMONTH	61	DIST(5,1)	0
MINJS	0.5000E+01	DIST(5,2)	0.3000E+00
MAXJS	0.7000E+01	DIST(5,3)	0.7406E+00
LABEQP	0.5000E+00	DIST(5,4)	0
DIST(1,1)	0	DIST(5,5)	0
DIST(1,2)	0	DIST(5,6)	0
DIST(1,3)	0	DIST(5,7)	0
DIST(1,4)	0.3500E+01	DIST(6,1)	0.9944E-01
DIST(1,5)	0.8333E+01	DIST(6,2)	0.6601E+00
DIST(1,6)	0	DIST(6,3)	-.3612E+00
DIST(1,7)	0.1800E+01	DIST(6,4)	0
DIST(2,1)	0	DIST(6,5)	0.5415E-01
DIST(2,2)	0	DIST(6,6)	0.2000E+00
DIST(2,3)	0	DIST(6,7)	0.2600E+01
DIST(2,4)	0.1000E+03	PRNOP1	0
DIST(2,5)	0.1681E+04	PRNOP2	0
DIST(2,6)	-.4500E+00	EXOPT1	1
DIST(2,7)	0.3200E+01	EXOPT2	0
DIST(3,1)	Varies	ISEED1	22092503
DIST(3,2)	0.4246E+00	ISEED2	897712097
DIST(3,3)	-.3167E+00	ISEED4	1417473372
DIST(3,4)	0	ISEED5	553645566
DIST(3,5)	0	ISEED6	755319619
DIST(3,6)	0	RATBC	10.0
DIST(3,7)	0	RATMMA	1000.0
DIST(4,1)	0	RATMMB	-.0001
DIST(4,2)	0.1500E+00	KB	0.2000E-02
DIST(4,3)	0.3750E+00	CB	0.1500E+01
DIST(4,4)	0	WMAX	0.1350E+03
DIST(4,5)	0	OPTJS	0.1000E+03

COMMENTS: Initial value of DIST(3,1) = 0.2287E+00.
This value is varied as shown in Table 5.1.

TABLE 4.6 -- BACKLOG INPUTS FOR MARKUP EXPERIMENTS, MARKET E

Variable	Value	Variable	Value
NEXPMT	1	DIST(4,6)	0
NSAMPL	1	DIST(4,7)	0
NMONTH	61	DIST(5,1)	0
MINJS	0.5000E+01	DIST(5,2)	0.3000E+00
MAXJS	0.7000E+03	DIST(5,3)	0.7406E+00
LABEQP	0.5000E+00	DIST(5,4)	0
DIST(1,1)	0	DIST(5,5)	0
DIST(1,2)	0	DIST(5,6)	0
DIST(1,3)	0	DIST(5,7)	0
DIST(1,4)	0.3500E+02	DIST(6,1)	0.4901E-01
DIST(1,5)	0.8333E+01	DIST(6,2)	0.3135E+00
DIST(1,6)	0	DIST(6,3)	-.1567E+00
DIST(1,7)	0.1800E+01	DIST(6,4)	0
DIST(2,1)	0	DIST(6,5)	0.6191E-03
DIST(2,2)	0	DIST(6,6)	0.2000E+00
DIST(2,3)	0	DIST(6,7)	0.2600E+01
DIST(2,4)	0.1000E+03	PRNOP1	0
DIST(2,5)	0.1681E+04	PRNOP2	0
DIST(2,6)	-.4500E+00	EXOPT1	1
DIST(2,7)	0.3200E+01	EXOPT2	0
DIST(3,1)	Varies	ISEED1	22092503
DIST(3,2)	0.3048E+00	ISEED2	897712097
DIST(3,3)	-.1756E+00	ISEED4	1417473372
DIST(3,4)	0	ISEED5	553645566
DIST(3,5)	0	ISEED6	755319619
DIST(3,6)	0	RATBC	10.0
DIST(3,7)	0	RATMMA	1000.0
DIST(4,1)	0	RATMMB	-.0001
DIST(4,2)	Varies	KB	0.2000E-02
DIST(4,3)	0.3750E+00	CB	0.1500E+01
DIST(4,4)	0	WMAX	0.1350E+03
DIST(4,5)	0	OPTJS	0.1000E+03

COMMENTS: Initial value of DIST(3,1) = 0.4901E-01.
This value is varied as shown in Tables 5.2 and 5.3.
For the first set of experiments, DIST(4,2) = 0.1500E+00.
For the second set of experiments, DIST(4,2) = 0.3000E+00.

CHAPTER 5

DISCUSSION OF RESULTS

Previous chapters have discussed the backlog model, a review of
the literature for each area of study in this thesis, and the research
methodology used by the writer to perform experiments with the BACKLOG
program. This chapter presents the results of the experiments perform-
ed by the writer and discusses the writer's interpretation of these
results for the three major areas of study:

1. Can the backlog model be used to identify an optimum
   level of capitalization for a given operation?

2. Can the model be used to explore the influence of project
   size on net profits?

3. Can the optimum markup be improved by accounting for the
   backlog of work?

5.1 Capitalization and Bonding Capacity

Two blocks of experiments were conducted to explore the areas of
capitalization and bonding capacity. The first set of experiments was
designed to determine if an optimum level of capitalization could be
identified for an operation with a predetermined bonding capacity. The
second set of experiments was designed to determine if an optimum
level of capitalization could be identified for an operation where the

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bonding capacity varies with the level of capitalization. The results of these two blocks of experiments are presented and discussed in subsections 5.1.1 and 5.1.2, respectively. The last two subsections discuss studies performed by the writer without the aid of the BACKLOG program. Motivation for these studies came from the results of previous experimentation. The writer recognized during experimentation that a self-adjustment of the level of capitalization may occur when a firm is unaware of the W versus U relationship. The results of this study are discussed in subsection 5.1.3. Subsection 5.1.4 discusses how the backlog model may be used to determine an optimum mix of working capital and operating capital for a given operation.

5.1.1 Optimum Capitalization with a Predetermined Bonding Capacity

Figure 5.1 presents the results of the experiments for a given operation with a predetermined bonding capacity. This figure shows that for all levels of bonding capacity a level of capitalization may be identified that maximizes net profits. For example, if the bonding capacity for the given operation is $1,800,000, the optimum level of capitalization corresponds to a mean monthly work completion rate of $230,000. This figure also shows that the optimum level of capitalization decreases as the bonding capacity increases.

Figure 5.1 may be examined from another perspective to gain insight into how a contractor should allocate available capital. For example, assuming that the contractor's bonding capacity is set at $2,000,000, a maximum of $180,000 should be allocated to field operations. If the contractor's actual working capital is $220,000, then $40,000 should be

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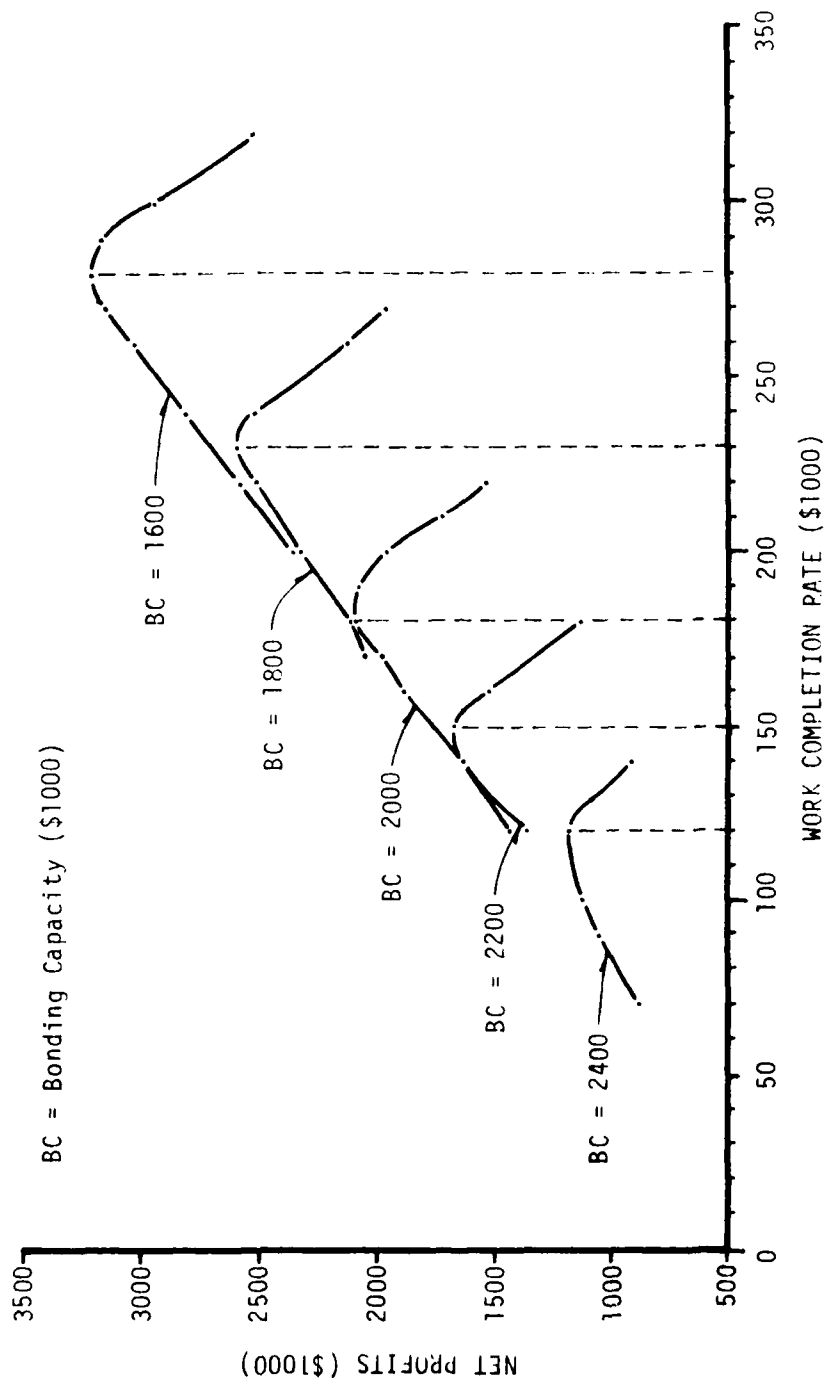
FIGURE 5.1 -- NET PROFITS AT VARIOUS LEVELS OF CAPITALIZATION

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allocated to some activity other than field operations. If the contractor is unaware of the backlog of work model and allocates all of his capital to field operations, net profits from field activities decrease approximately 30% and total company net profits may decrease more due to the loss of potential revenues that the $40,000 may have generated. Bonding capacity may also be studied in Figure 5.1.

Assuming that the methods of collecting short-term receivables and paying short-term liabilities do not change and that leverage remains constant, the level of capitalization for a given operation changes only with changes in the amount of working capital available for field operations. An increase in operating capital suggests that the bonding capacity would typically increase if a decrease in the ratio of short-term assets to short-term liabilities has not occurred. The results of the above experiments are, however, contrary to this concept. For example, Figure 5.1 shows that, if the contractor's mean monthly work completion rate (level of capitalization) is $280,000, the bonding capacity for the operation is established at $1,600,000. This suggests that the bonding capacity should be set at or greater than 6 times the amount of capital available for field operations. Using the standard rule-of-thumb for setting bonding capacity at 10 times the working capital, one may have anticipated that at this level of capitalization the bonding capacity may have been established at approximately $2,800,000. If the contractor's monthly work completion rate is only $150,000, the bonding capacity should be set at or lower than $2,200,000. This suggests that the bonding capacity for this level of capitalization should be established at or less than 15 times the level of capitalization.

For this case, the general rule-of-thumb may be more restrictive than necessary considering the contractor's potential to operate efficiently at higher backlogs of work. These experiments indicate that the backlog model and level of capitalization could provide additional inputs into the establishment of a firm's bonding capacity.

The logic behind the scenarios presented above may best be understood by examining the backlog of work curve for the operation studied. Figure 5.2 shows this curve and the five levels of bonding capacity studied. It was initially found that the optimum level of capitalization for a given bonding capacity occurs such that the contractor apparently assumes inefficient operations at high backlogs of work (as shown by the hatched areas). Further study revealed, however, that because the backlog of work is updated prior to predicting the monthly work completion rate, no inefficiencies actually occurred. This updating process is shown in Figure 5.3. The variable, X, in this figure represents the range of backlog associated with apparent inefficiencies of operations up to the bonding capacity, point A. This range is equivalent to the mean monthly work completion rate, and, prior to predicting this rate for the next month, the backlog is adjusted to point B to reflect work completed during the month. It is noted that this procedure is applicable for all levels of capitalization. To predict the mean monthly work completion rate for an operation directly from a curve, one must construct a prediction backlog of work curve by iterating the above process at all possible levels of capitalization. Figure 5.3 shows the fitted curve (solid) and the prediction curve (dotted) for the given operation.

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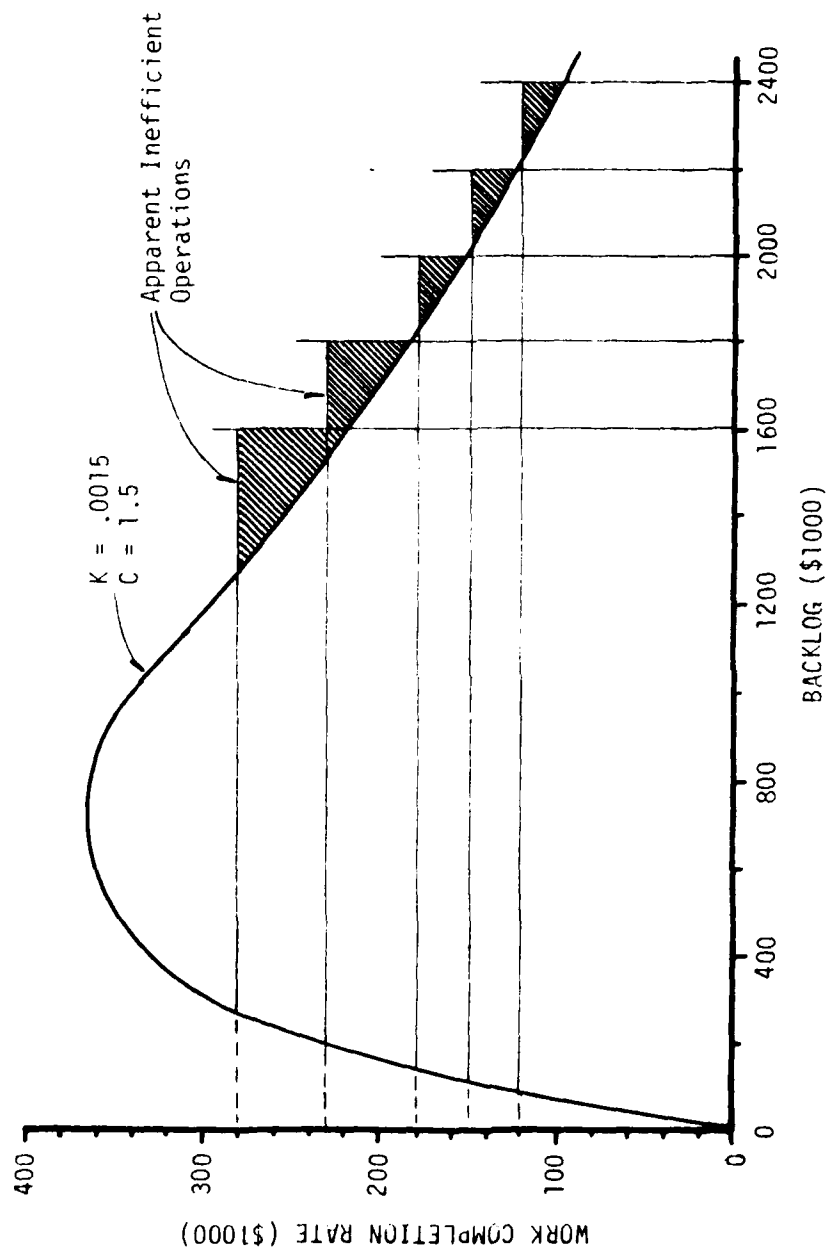
FIGURE 5.2 -- IDENTIFYING THE OPTIMUM LEVEL OF CAPITALIZATION

67
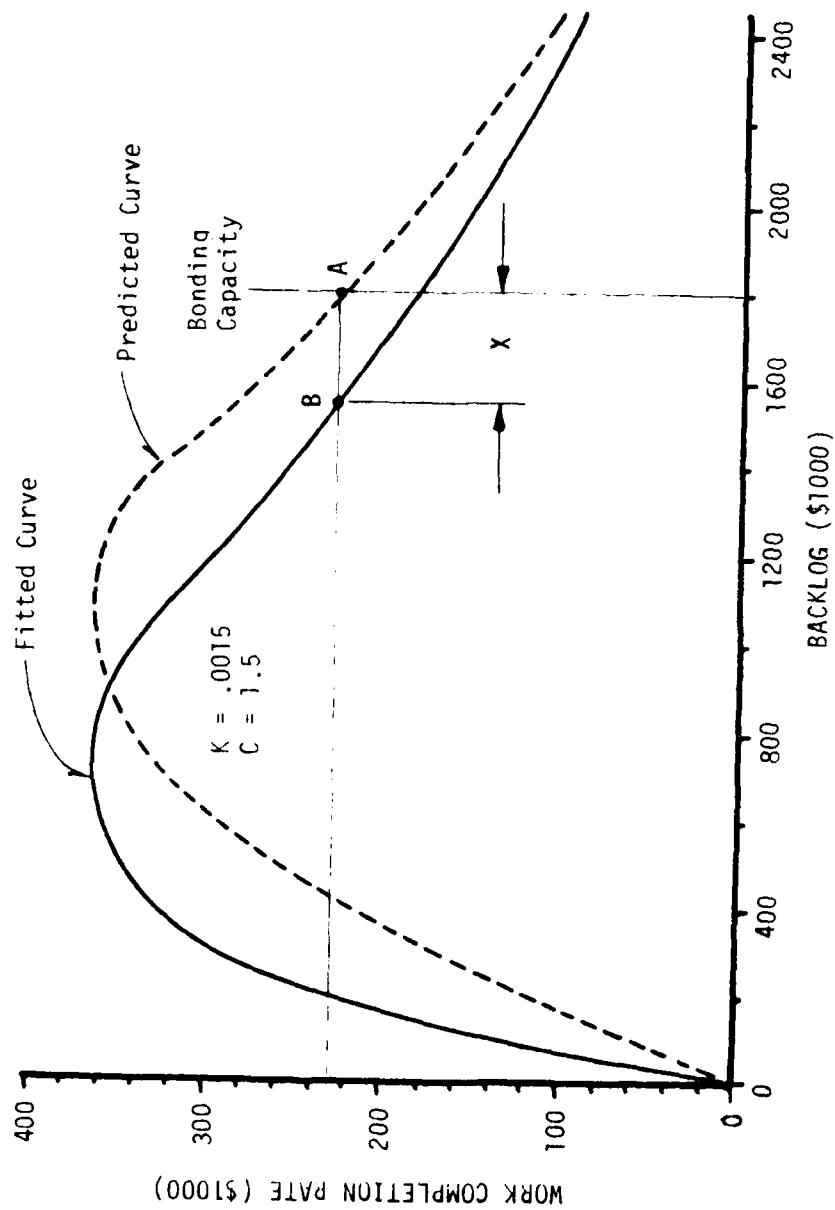
FIGURE 5.3 -- FINDING THE PREDICTION BACKLOG CURVE

Fitted and prediction backlog of work curves for a variety of operations are presented in Appendix E. Figure 5.4 shows the optimum level of capitalization for each of the five bonding levels studied in this section, using the prediction curve. Since the optimum level of capitalization for a given bonding capacity appears to be located where a vertical projection from the bonding capacity intersects the prediction curve, one may use the curve to predict, for example, that the optimum level of capitalization for this operation with a bonding capacity set at $1,400,000 is $330,000 (the mean monthly work completion rate). It is not necessary to simulate operations if a variety of prediction curves are available since the optimum (and maximum) level of capitalization may be identified directly from a curve or set of curves by interpolation.

A common criticism of the construction industry, as mentioned in Chapter 3, is that the typical contractor is highly undercapitalized. Previous discussion in this section has suggested that one may identify an optimum level of capitalization for a given operation with a predetermined bonding capacity and that a contractor may be either over-apitalized or undercapitalized to the same degree with respect to this optimum level and maintain roughly the same level of profitability from field operations (see Figure 5.1). At higher levels of capitalization, the contractor's potential increase in net profits due to a greater turnover in working capital is offset by inefficient operations at higher levels of backlog (assuming the contractor strives to maintain a backlog that approaches his bonding capacity). At lower levels of capitalization, net profits decrease due to a slower turnover in working
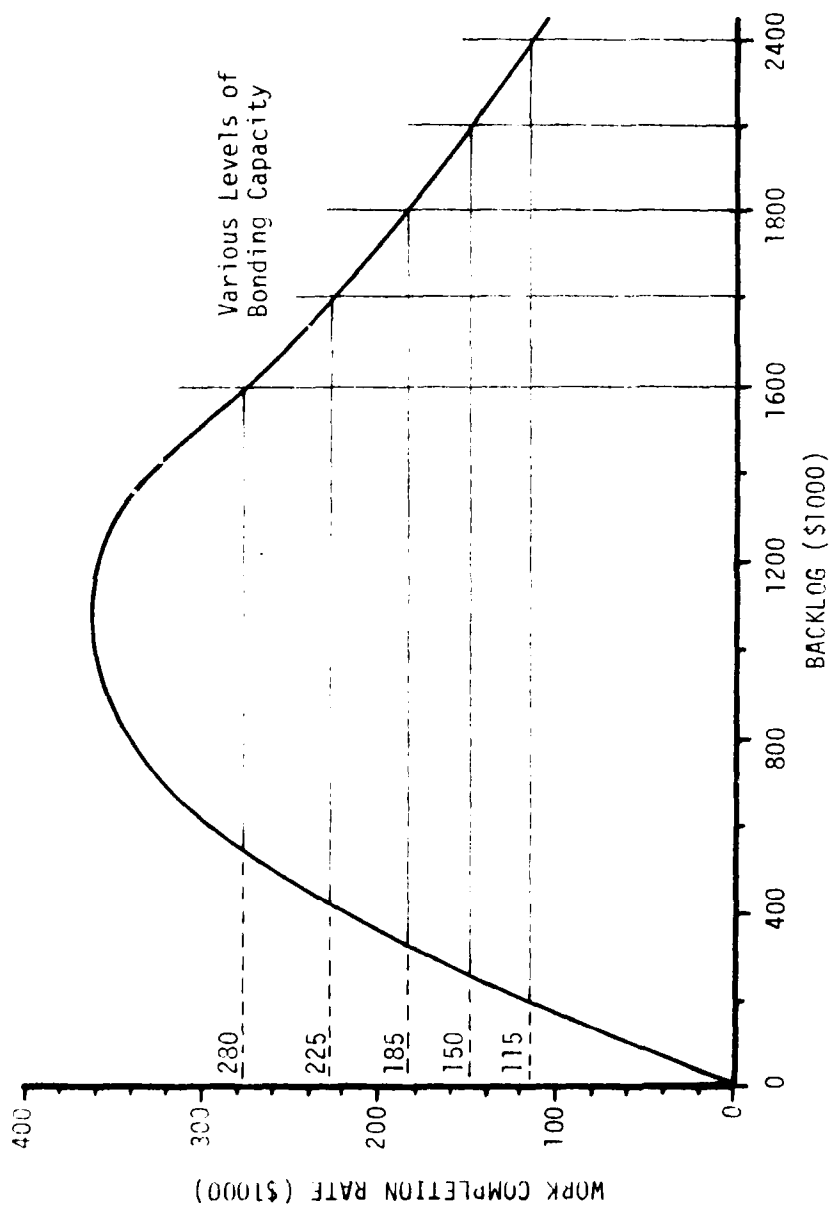
FIGURE 5.4 -- ESTIMATING THE OPTIMUM LEVEL OF CAPITALIZATION

capital from field operations. It would therefore seem wise for a contractor to always be undercapitalized from this optimum level while using remaining working capital for other investments. This suggests that, at least to some degree, the criticism is unwarranted.

An outstanding investment for any capital above the optimum level of capitalization would be one that achieves an improvement in the relationship between the backlog of work and the monthly work completion rate. Such an investment, if well planned and integrated into the total company operation, would expand company potential and allow for controlled growth if desired. This concept is demonstrated in Figure 5.5. It is assumed that the contractor in this scenario is currently working at the optimum level of capitalization of $120,000 with a bonding capacity established at $1,600,000 (point A). If the contractor makes an investment to improve communications and information collection, it is estimated, for example, that the decision making time interval will decrease from $K = 0.002$ to $K = 0.0015$. This improvement in the backlog/work completion rate relationship has helped the contractor in several ways. First, the contractor may direct more capital to field operations as they become available (up to point B) without incurring inefficient operations. Second, the contractor may elect to strive for an increase in bonding capacity (up to point C) while holding the capitalization of field operations constant. This move may provide greater flexibility in the type and size of project the contractor may bid in the market. Third, the contractor may strive for a combination of the above strategies, as shown by point D. This third strategy is aimed at controlled growth in both the level of capitalization and the allowable bonding

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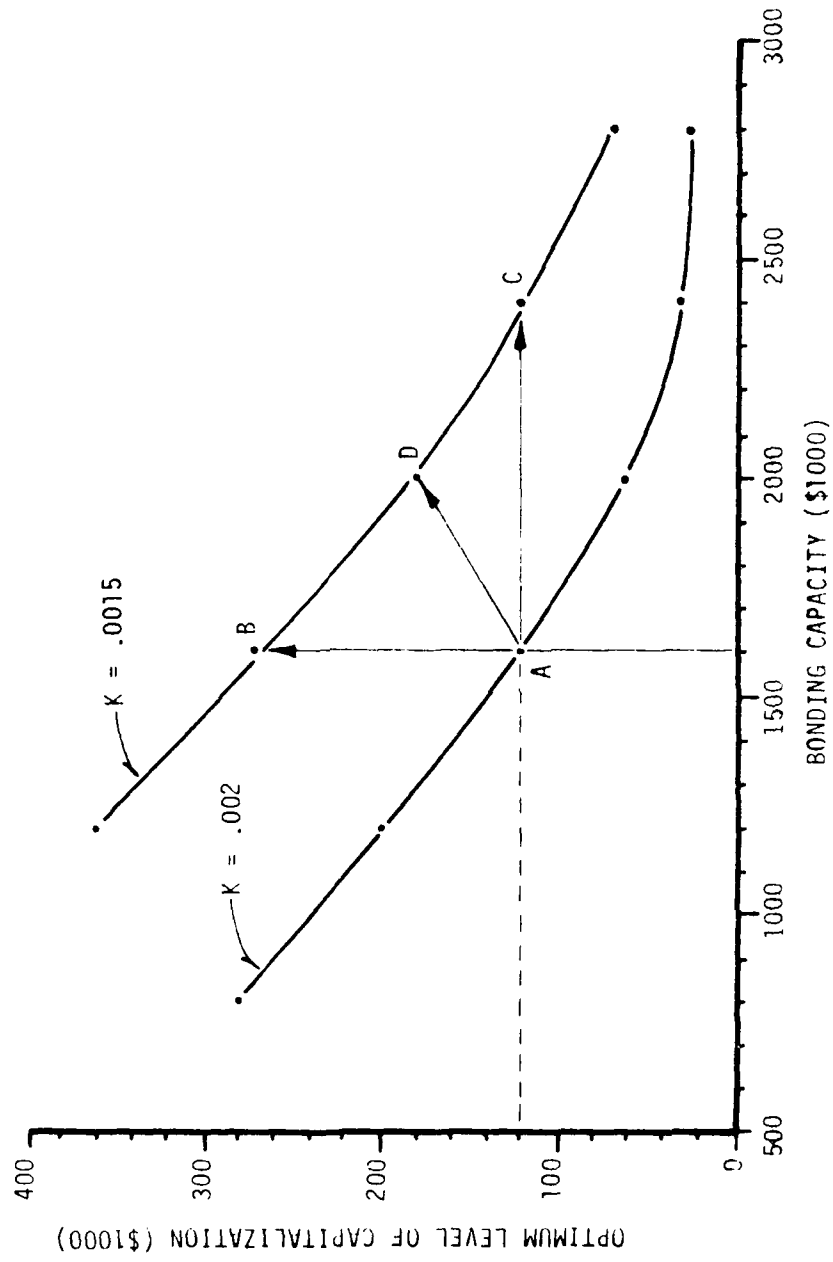
FIGURE 5.5 -- IMPROVING CONSTRUCTION OPERATIONS

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capacity.

5.1.2 Optimum Capitalization with a Variable Bonding Capacity

While bonding capacity was assumed to be predetermined in the previous experiments, bonding capacity is assumed to be a function of working capital for the experiments in this section. Figure 5.6 shows that bonding capacity (points A', B' and C') is set at 10 times the mean monthly work completion rate (points A, B and C). The hatched areas in this figure represent the range of backlog with inefficient operations. It was found tnat an optimum level of capitalization could be identified for a given operation with bonding capacity varying with the level of capitalization. Figure 5.7 shows a typical plot of net profits versus the mean monthly work completion rate for several of the experiments in this study. This figure shows that net profits decrease very rapidly at levels of capitalization greater than the optimum level. This differs from the results in this previous section because bonding capacity increases with capitalization and the range of inefficient operations increases as shown in Figure 5.6. Additional plots of the results for all of the experiments in this section are not presented in this thesis, but they may be obtained by replicating the experiments using the inputs outlined in Chapter 4. For each set of experiments run, the optimum level of capitalization was identified and used for further study.

Analysis of the optimum level of capitalization for each experiment suggested that a strong relationship exists between this optimum level and the parameters C and K in the backlog of work model. Figure 5.8 shows the relationship between the optimum level of capitalization and

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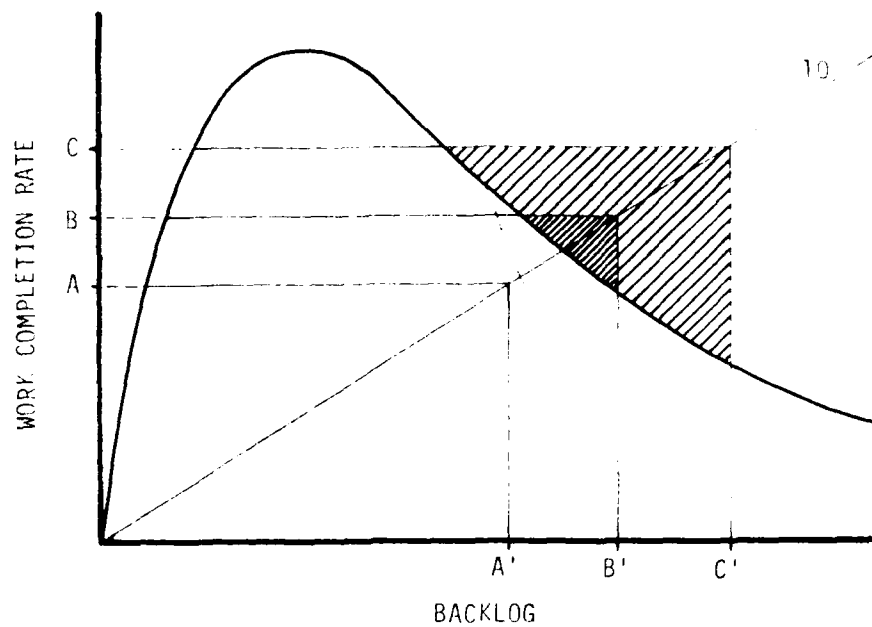
FIGURE 5.6 -- BONDING CAPACITY AND WORKING CAPITAL
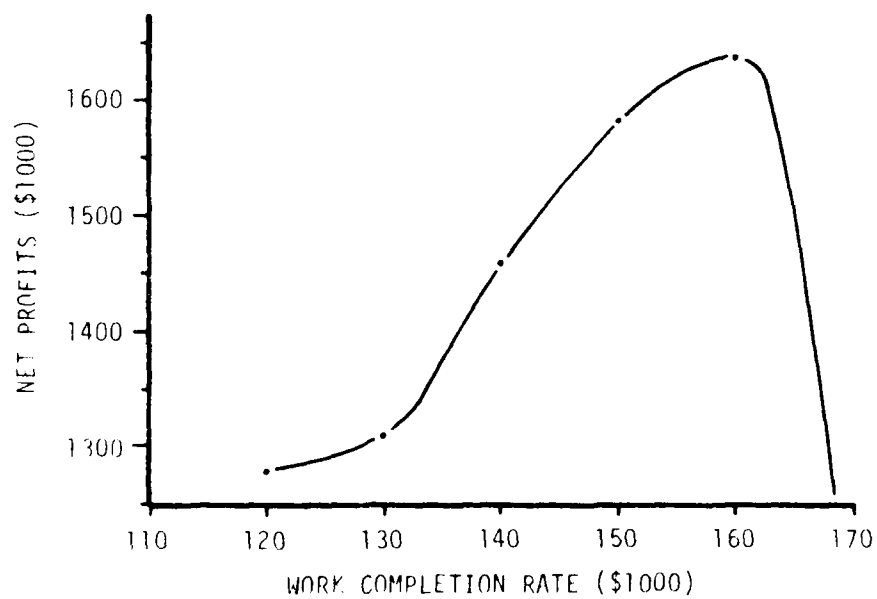
FIGURE 5.7 -- NET PROFITS WHEN BONDING CAPACITY
VARIES WITH WORKING CAPITAL

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the decision making time interval parameter, K, for 4 levels of the perceived opportunity for achievement parameter, C. Figure 5.9 shows the relationship between the optimum level of capitalization and the parameter C for 4 levels of the parameter K. These two figures were used to construct the joint response of optimum capitalization for the parameters K and C, as shown in Figure 5.10. This figure may be used to determine the optimum level of capitalization for any given operation where bonding capacity is set at 10 times the level of capitalization. For example, during his studies, Larew found that the parameters K and C were equal to 0.001476 and 0.4491, respectively, for one specific time period in the company's history (14:150). Using Figure 5.10, we may predict that the company's optimum level of capitalization during that time period was $110,000 if the assumptions associated with the development of this figure are met: bonding capacity is established at 10 times the working capital and all working capital is available for field operations. It is interesting to note that the mean monthly work completion rate for the company operation during the time period was $110,000 (14:150).

The important point of the above example is not that perhaps by coincidence the assumptions were met but that the methodology for determining the optimum level of capitalization is the same regardless of the assumptions made. Optimum capitalization plots, such as the one shown in Figure 5.10, may be developed for a variety of relationships between working capital and the mean monthly work completion rate, working capital and bonding capacity, leverage and the mean monthly work completion rate, operating capital and working capital, etc.

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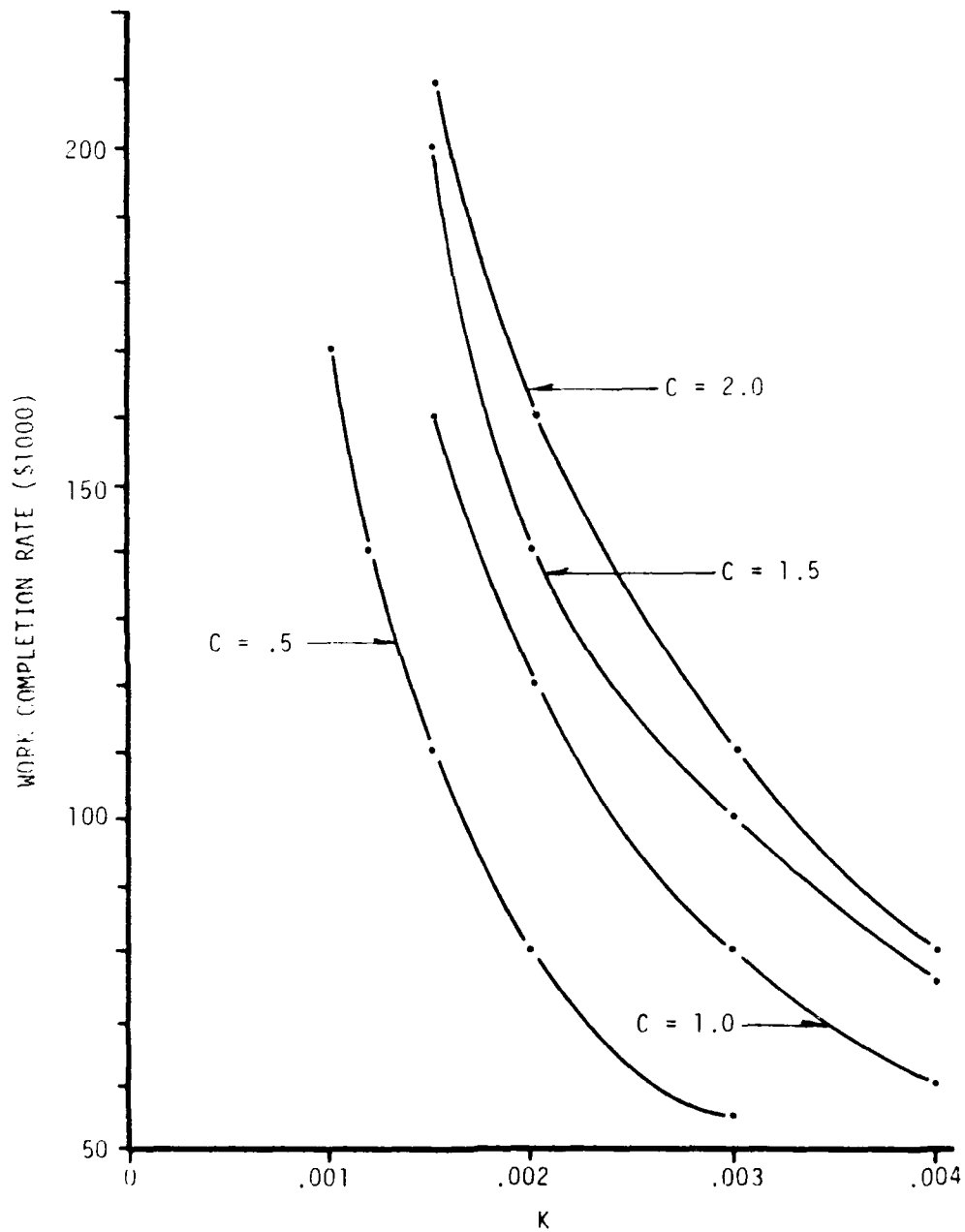
FIGURE 5.8 -- OPTIMUM LEVEL OF CAPITALIZATION VERSUS K
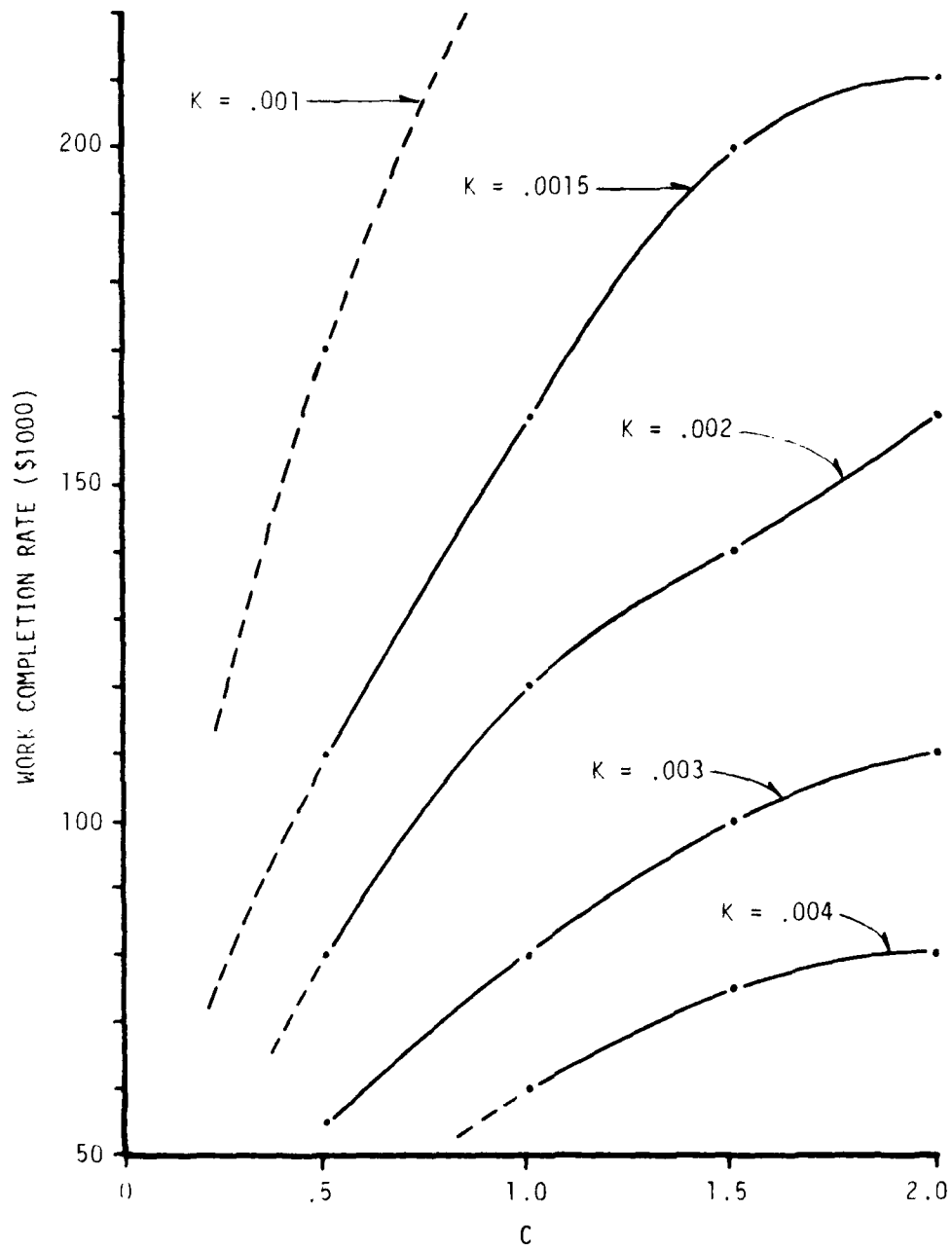
FIGURE 5.9 -- OPTIMUM LEVEL OF CAPITALIZATION VERSUS C

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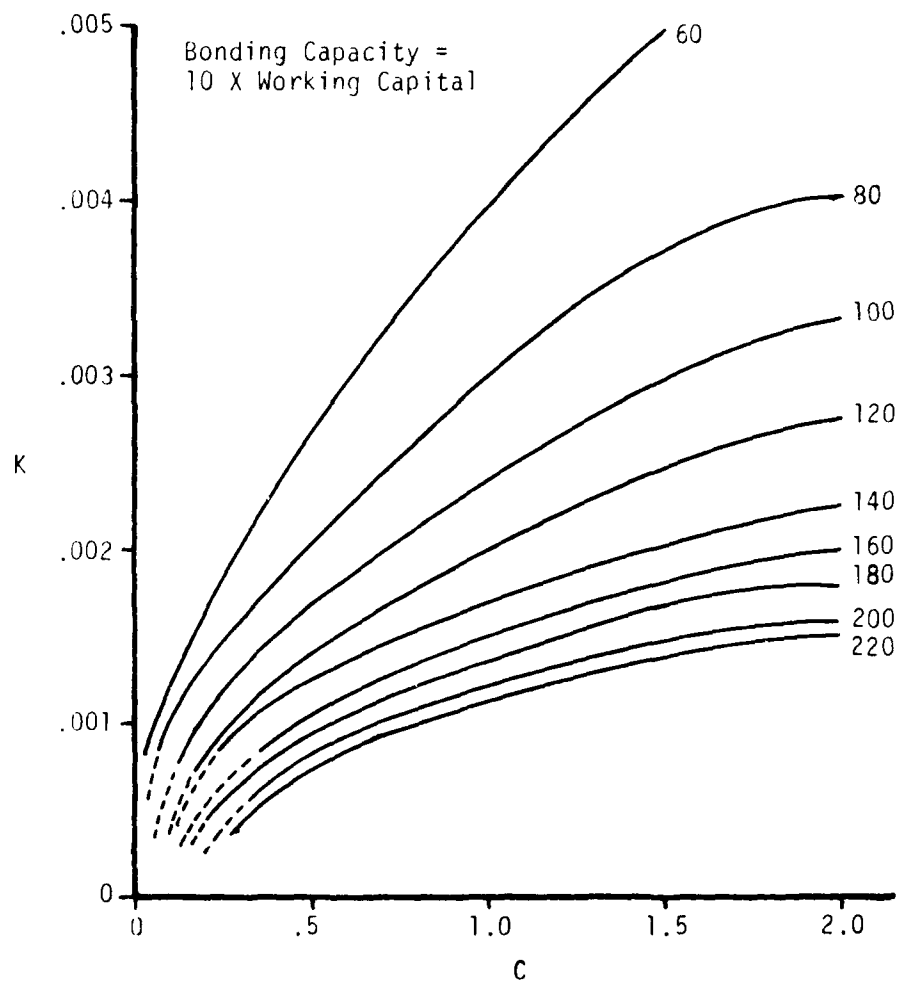
FIGURE 5.10 -- OPTIMUM LEVEL OF CAPITALIZATION RESPONSE
CURVES ($1000)

These figures might then be used to determine the optimum level of capitalization for the actual environmental and internal constraints for a given operation.

5.1.3 The Self-Adjusting Principle

How much capital should be allocated to field operations to maximize operational net profits or satisfy some other objective? Previous subsections in this section report the results of several experiments addressing the areas of capitalization and bonding capacity and suggest that the backlog of work model may be used to pursue an answer to the above question. However, until this or some other model is further refined and tested in the field, managers must continue to conceptually determine how much working capital should be allocated to field operations.

We know that the work completed by an enterprise varies with changes in operating capital. Operating capital can be increased by allocating more working capital to the field or by directing profits to field operations. Operating capital can be decreased by pulling capital away from field operations, i.e., when costs exceed billings due to under-estimating or overrunning costs. Very few construction firms are capable of doing business for any length of time without experiencing changes in the monthly work completion rate and the level of field capitalization. The previous work of Larew (14) and the insight gained from the study of the backlog model suggest that there may be a "self-adjusting principle" that will help explain why the work completion rate varies (excluding seasonal factors, project start-ups, etc.) and

why some firms lose capital due to cost overruns.

There are three primary reasons a firm may appear to be overcapitalized with respect to the backlog of work curve for the given operation. First, a firm may direct more operating capital to the field to increase the monthly work completion rate, as shown in Figure 5.11(a). In this figure, operating capital is first increased to increase the work completion rate from W to W'. The corresponding range of backlog for efficient operations is decreased from A-B to A'-B'. Another increase in operating capital increases W' to W" and the range of efficient operations decreases from A'-B' to A"-B". Assuming that bonding capacity does not change, these increases in operating capital may constitute overcapitalization if the backlog of work at any time exceeds the range of efficient operations. Second, a change of modus operandi may cause a decrease in operational potential, as shown in Figure 5.11 (b). If it is again assumed that the bonding capacity does not change, the shift in modus operandi decreases the range of efficient operations from A-B to A'-B' and the firm may appear overcapitalized with the new backlog of work curve if the backlog is at any time outside the range of efficient operations. Third, a change of modus operandi that reflects improved operational potential may constitute apparent overcapitalization, as shown in Figure 5.11(c). A change in the backlog of work curve may decrease the range of efficient operations from A-B to A'-B'. If at any time the backlog of work for the new modus operandi is less than A', the firm appears to be overcapitalized because the mean monthly work completion rate decreases.

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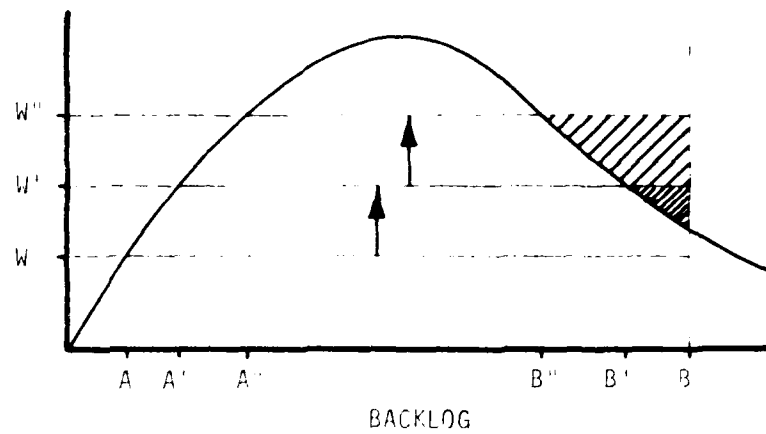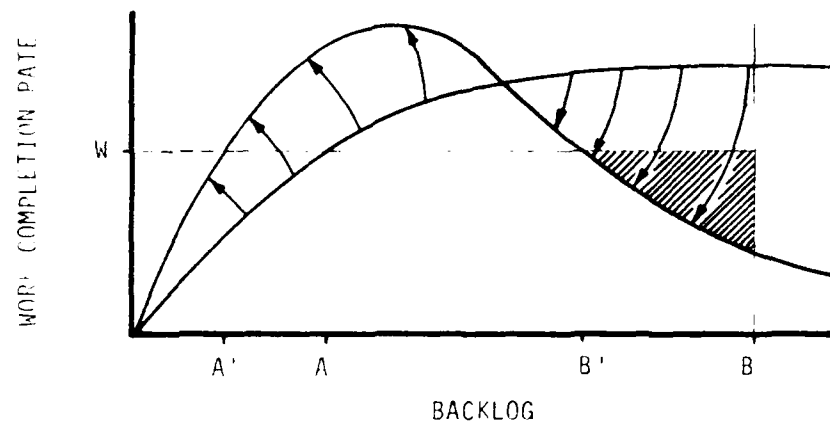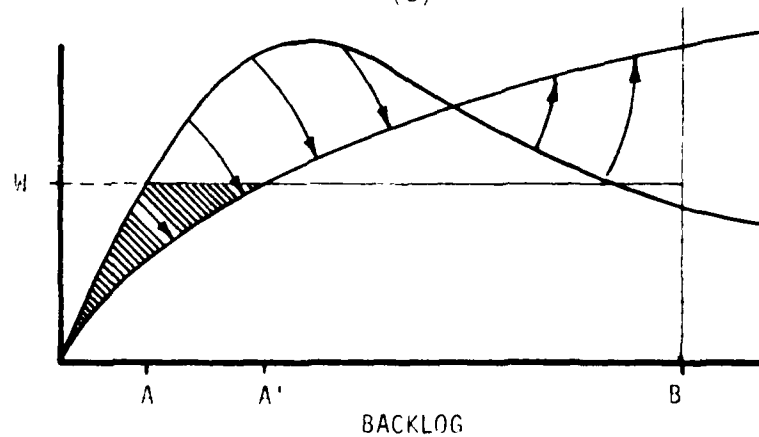
FIGURE 5.11 -- REASONS FOR APPARENT OVERCAPITALIZATION

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The above changes in the level of capitalization or modus operandi lay the foundation for the self-adjusting principle. This principle may best be explained by developing a scenario that is illustrated in Figure 5.12. It is assumed that we are examining a given operation undergoing only changes in the level of field capitalization. The scenario begins with the firm operating at a monthly work completion rate of W as shown in Figure 5.12(a). Firm executives have decided to raise operating capital to achieve an increase in the work completion from W to W'. Points on the W' line are highlighted to indicate the levels of backlog experienced by the firm at this new level of capitalization. The apparent overcapitalization with respect to the backlog of work curve is not noticed since backlog never exceeds the range of efficient operations. (The reader is reminded that the decision maker for the firm is not familiar with the backlog of work model and that he/she simply anticipates increases in monthly billings due to increases in operating capital.) Several months later, the firm anticipates winning a sizeable project and again increases field capitalization to W" in an effort to gear up for an increase in the backlog of work. The project is won and the backlog of work is increased to point A. Unfortunately, overcapitalization may now become apparent since the backlog of work is outside the range of efficient operations. The decision maker is not aware that field operations are overcapitalized and notices only that the work completion rate drops from W" to W"' for no apparent reason. The drop in the work completion rate is the result of cost overruns since the decrease is due solely to operational inefficiency at the high level of backlog. A drop in capitalization should ensue due to these

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cost overruns, as shown in Figure 5.12(b). If this drop does not occur and the company attempts by some means to keep field capitalization high, the impact may be disasterous (i.e., lead to eventual financial failure). Hopefully the cost overruns will be recognized through accurate field cost reporting and analysis by either home or field office personnel, and adjustments may be made to improve the backlog of work curve or keep the level of field capitalization low until backlog is reduced. The project is labelled a "loser" by the company: the exact cause is unknown, although poor cost estimating or poor field supervision may be implicated. Figure 5.12(c) suggests that a cycle similar to the above scenario may occur repeatedly: some projects are "winners" and some are "losers." This figure suggests that the firm is experiencing a self-adjustment around the unknown optimum level of capitalization for the given operation (shown by the heavy W-line).

It is understood by the writer that the self-adjusting principle and all associated assumptions are an extreme simplification of a complex and dynamic environment. The usefulness of this principle in explaining recognized deviations in the work completion rate (and level of capitalization) may be reinforced by examining the backlog of work over time for an actual company operation (14:149-152). Data available to the writer included the work completion rate and backlog of work of an enterprise for 60 months, and the total time is divided into 12 periods with predetermined values for the parameters K and C in the backlog of work model. It is assumed that the values for these parameters accurately describe the firm's operational potential during each period. Figure 5.13 shows a plot of the backlog of work versus time

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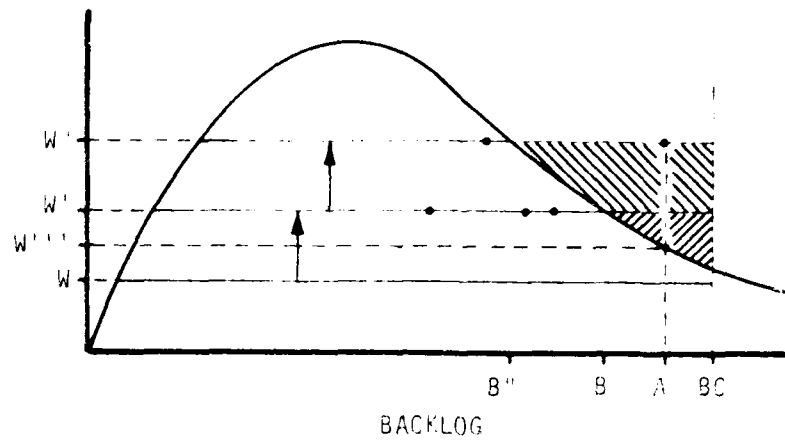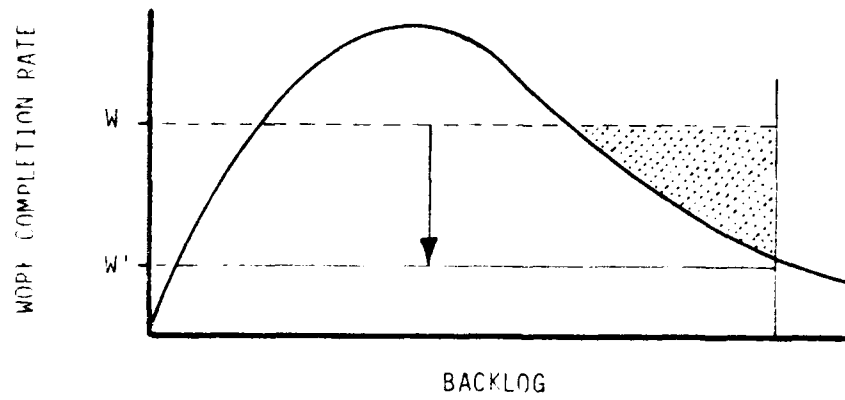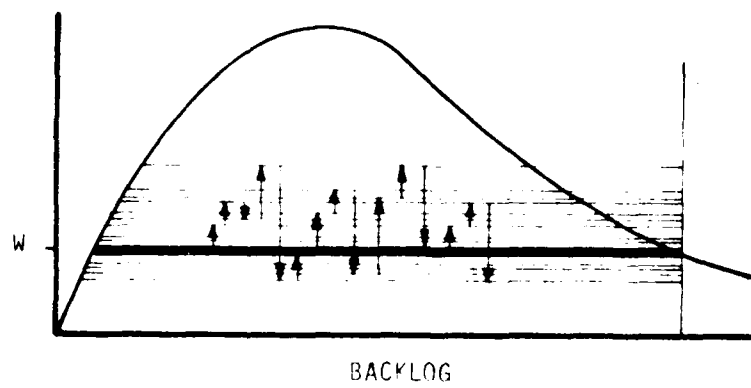
FIGURE 5.12 -- THE SELF-ADJUSTING PRINCIPLE

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and the apparent range of backlog for efficient operations is between the dotted lines for each period. These ranges were determined by interpolating the low and high backlogs for efficient operations from the prediction curves presented in Appendix E or by constructing the actual prediction curve for the given operation (given values of K and C). The hatched areas in Figure 5.13 represent levels of backlog outside the range of efficient operations. From these hatched areas and remembering the foundations of the self-adjusting principle, one may predict that:

1. Halfway through period C a decrease in W is predicted since the backlog of work at the beginning of the period was greater than the operation could efficiently handle.

2. At the end of period E and the beginning of period F, a decrease in W is predicted since the backlog is too low for efficient operations. It is predicted that W increases in period F since the backlog is within the range of efficient operations but decreases and stays low until the beginning of period G since the backlog again is too low for efficient operations.

3. Halfway through period G a decrease in W is predicted. It is predicted that W will remain low through period H since the backlog is too low for efficient operations.

4. It is predicted that W will decrease at the beginning of period K until halfway through the period since the backlog is too low. Toward the end of period K an increase in W is predicted but it is predicted that W decreases at the beginning of period L when the backlog again becomes too low for efficient operations.

Time Period

Apparent Range for
Efficient Operation.
(Typical)

1000
900
800
700
600
500
400
300
200

BACKLOG ($1000)

A B C D E F G H I J K L
Unt.

0   10   20   30   40   50   60
TIME (MONTHS)
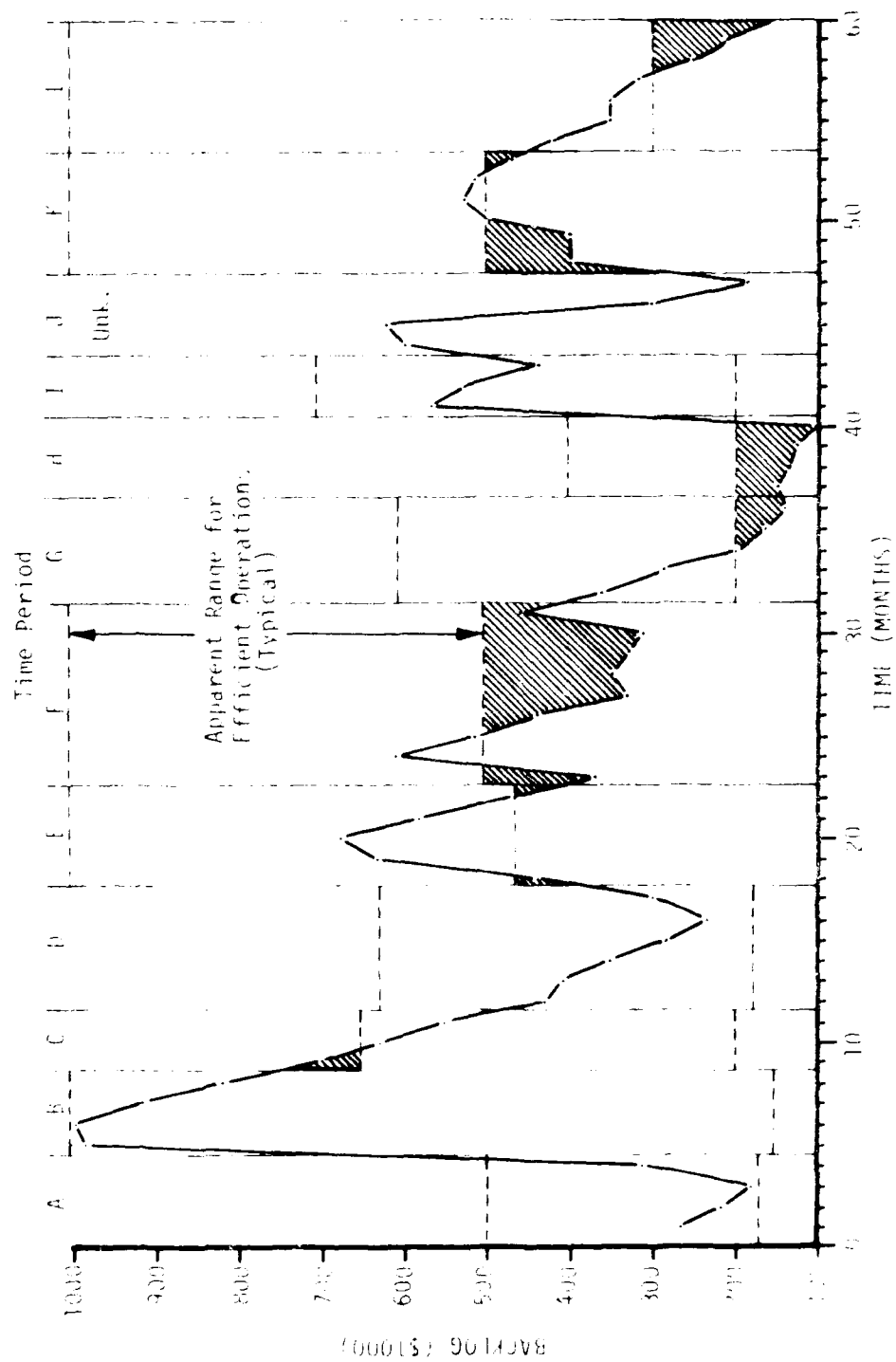
FIGURE 4.13 CHANGES IN BACKLOG OVER TIME
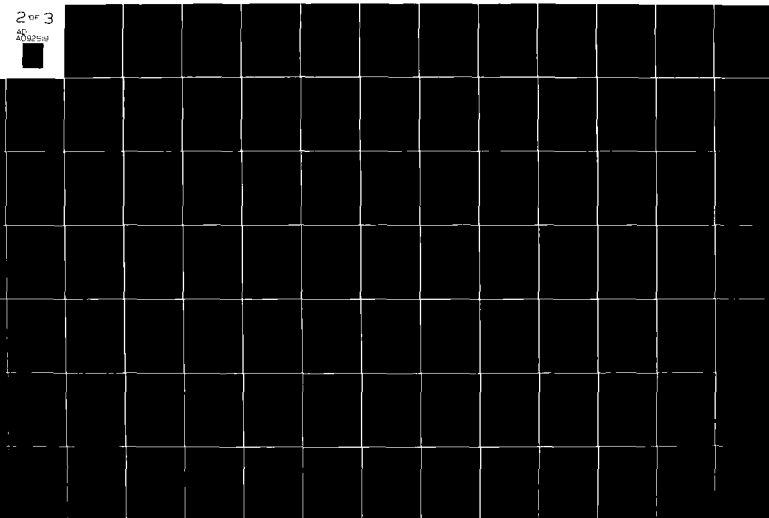
5. Halfway through period L a decrease in W is predicted when the backlog becomes too low.

Each of the above predictions is based on apparent overcapitalization due to changes in modus operandi since no data is available on intentional financial adjustments. The predictions may now be compared to the actual changes in the work completion rate experineced by the firm, as shown in Figure 5.14. One may note that to a great degree the predictions are correct: changes in modus operandi caused apparent overcapitalization and the work completion rate adjusted accordingly.

5.1.4 Working Capital and Operating Capital

The backlog of work model may be used to determine the optimum level of capitalization for any operation and any set of assumptions or constraints addressing operating capital, working capital and bonding capacity. Assume, for example, that the bonding capacity for a given operation is set at 10 times the working capital and that working capital is unrelated to operating capital. Figure 5.15 shows how the backlog prediction curve may be used to determine the optimum level of field capitalization for any level of working capital. The firm in case A has $240,000 of working capital upon which bonding capacity is based. To determine the optimum level of operating capital, a horizontal projection is made from the working capital axis at $240,000 until the projection intersects the 10-times iso-bonding line. A vertical projection is then made from this intersection until the projection intersects the backlog curve. From this second intersection a horizontal projection is made to the work completion rate axis to determine the
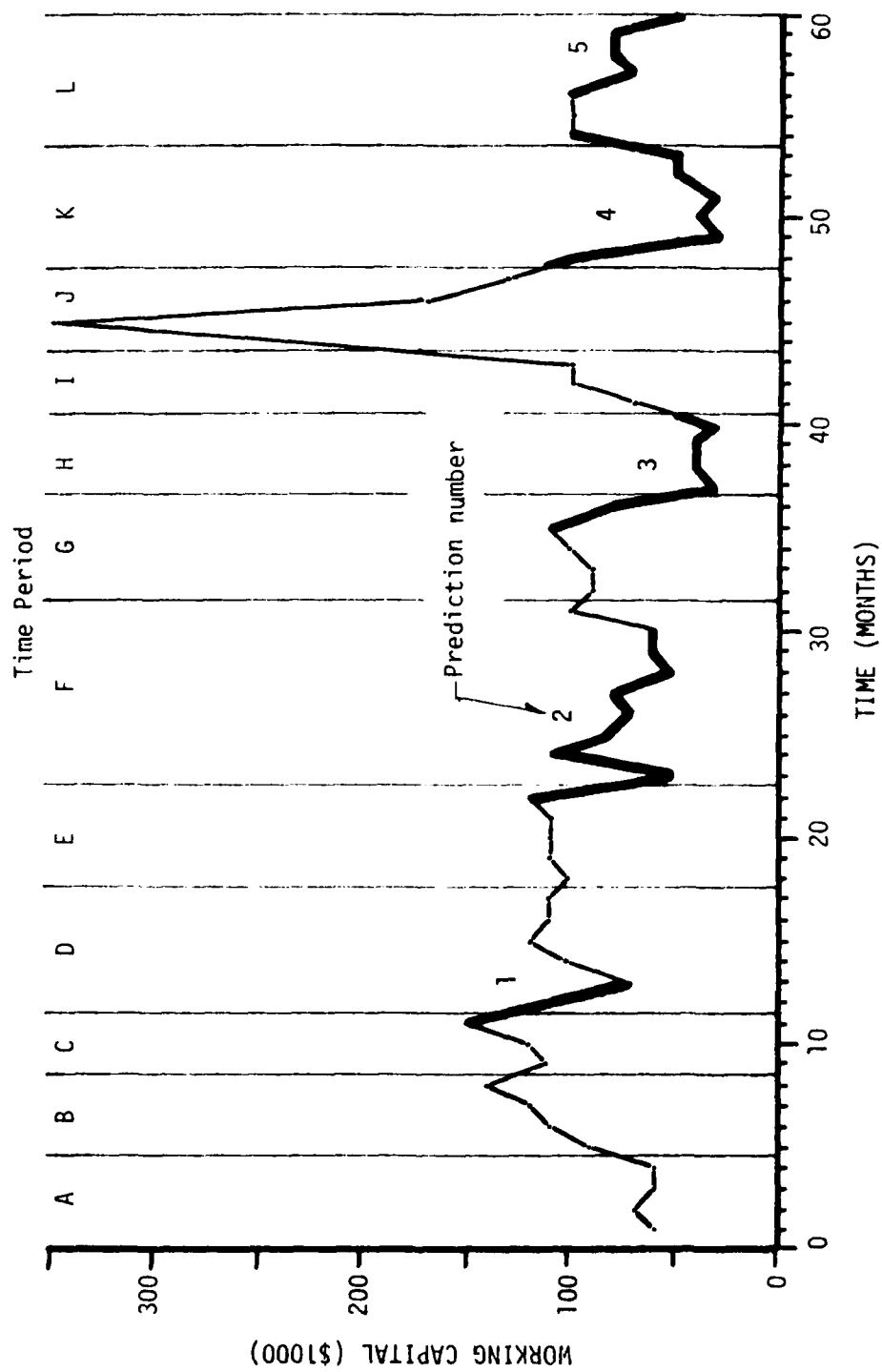
FIGURE 5.14 -- CHANGES IN WORKING CAPITAL OVER TIME

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optimum mean monthly work completion rate for the operation. This rate
is a measure of the optimum level of field capitalization by the work
completion rate function. The above process is used to determine the
optimum level of field capitalization for cases B and C in Figure 5.15.

An implicit assumption in the above example is that the firm does
not exercise constraint in the backlog of work between zero and the
bonding capacity. The firm bids work if it is available and, if won,
is within the allowable backlog set by the company's surety. The above
process would be used primarily for descriptive and analytical purposes.
The process is not applicable if the firm is aware of the constraints
imposed by the backlog of work model and exercises constraint in bid-
ding work such that the backlog of work is partially controlled. (Back-
log from competitively bid work may never be totally controllable unless
the probability of winning every project is 1.0.) This concept is pre-
sented in Figure 5.16. Regardless of the level of working capital,
field operations may be capitalized at any level if the backlog of work
at all times remains within the range of efficient operations. The
example shown in Figure 5.16 is the same as case A in Figure 5.15. If
the firm is unaware of the backlog model, the optimum level of field
capitalization is W and the range of efficient operations is A-B (found
by the previously explained process). If the firm is aware of the
backlog model and the prediction curve for the operation, the firm may
increase the level of field capitalization to, for example, W' but the
range of efficient operations decreases from A-B to A'-B'. Another in-
crease in capitalization from W' to W" decreases the range of efficient
operations from A'-B' to A"-B". Each of these strategies is effective
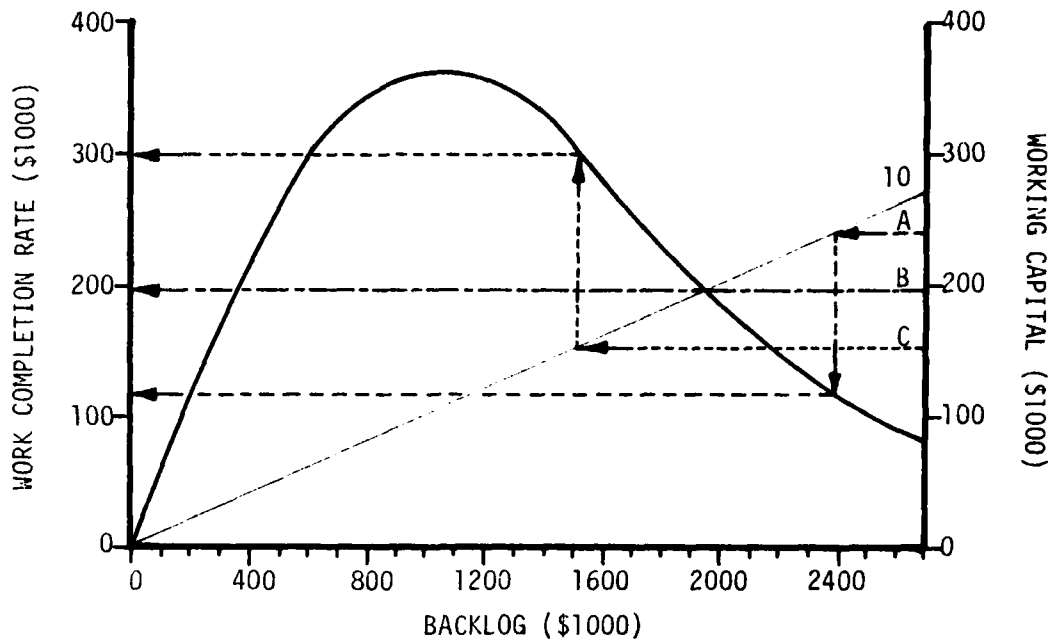
FIGURE 5.15 -- WORKING CAPITAL AND THE OPTIMUM LEVEL
OF OPERATING CAPITALIZATION
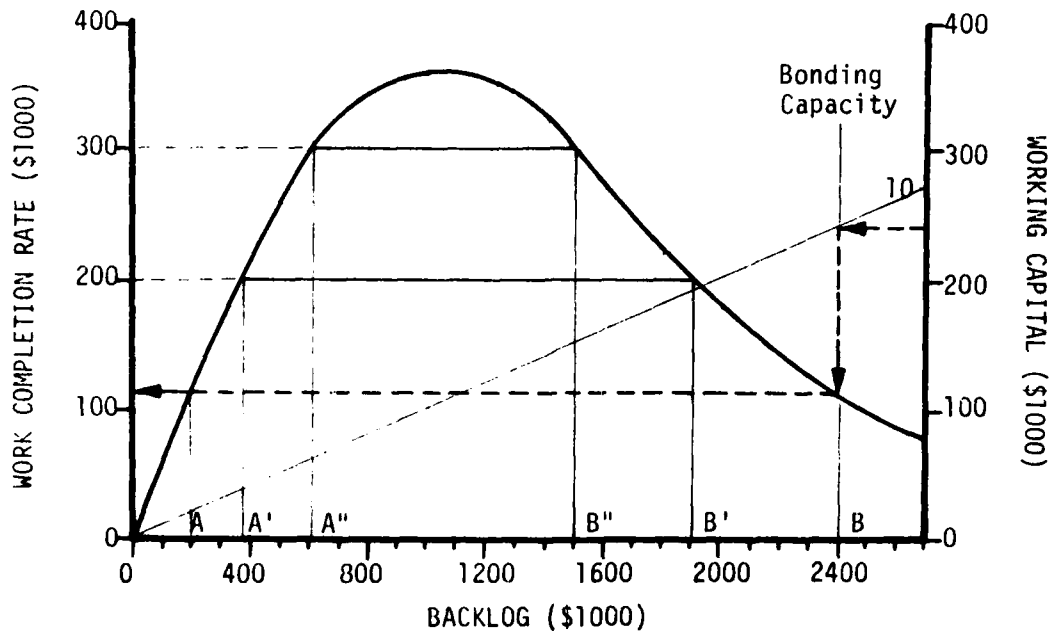
FIGURE 5.16 -- CONSTRAINING BACKLOG TO INCREASE
OPERATING CAPITAL

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if the backlog of work never exceeds the range of efficient operations. If this happens, the actual work completion rate decreases while the level of operating capital is held constant. One may question if the range of backlog A"-B" provides sufficient flexibility in the competitive bidding environment. If the above firm's bid/get ratio is, for example, 15 to 1 and the firm by chance wins 14 of the next 15 bids, it is probable that adjustments to the level of field capitalization must take place for the firm to efficiently accomodate a higher level of backlog.

One may question the responsiveness of a firm and the accuracy of predictions using the backlog model and wonder if the above tactics are useful. For this question the writer has no firm answer; however, as with other strategies mentioned in this thesis, it would be wise for a manager to make conservative decisions. The last case presented in Figure 5.16 would be interpreted by the writer to be unwise in a highly competitive or volatile market.

5.2 Project Size

The previous section in this chapter discussed how the backlog model may be used to explore the areas of working capital and bonding capacity. The results reported and discussed in this section address the impact of project size on net profits. The first block of experiments was designed to identify a maximum project size for a given operation. The second block of experiments was designed to examine the impact of project size for a variety of operations and levels of capitalization. The results of these two blocks of experiments are reported and discussed in Subsections 5.2.1 and 5.2.2, respectively. The last

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subsection attempts to integrate the findings of the above experiments with the previous work of Larew and Grieve.

5.2.1 Maximum Efficient Project Size

Prior to experimentation with the BACKLOG program, it was determined that the maximum range of backlog for efficient operations (MAXPRO) may be a measure of the maximum project size that a company should consider bidding under optimum conditions. Any project size exceeding MAXPRO causes company operations to become inefficient at either high or low levels of backlog according to the backlog of work model. This concept is presented in Figure 5.17. For all levels of capitalization for a given operation, the maximum range of efficient operations is constrained at low levels of backlog by the backlog of work curve and at high levels of backlog by either the bonding capacity (Cases A and B) or the backlog of work curve (Case C). It is emphasized that MAXPRO is a measure of the maximum project size for a given operation only under optimum conditions with respect to the backlog of work and not necessarily a measure of the maximum project size if these conditions are not met. This point is best illustrated by examining Case C in Figure 5.17. MAXPRO-C is a measure of the maximum project size that the company should bid only if every project bid and won is awarded when the company's backlog of work is at point C'. As soon as the project is awarded to the contractor, the backlog of work is immediately increased to point C", the high backlog of efficient operations. This example requires perfect market and company conditions that are

virtually impossible to satisfy. Under normal market and company conditions, the maximum project size the company should consider is some value less than MAXPRO-C. This project size must allow for flexibility in bidding to account for the level of backlog at the time of potential award and the random distribution of project sizes available in the market at any given time. One may assume, for example, that a project size equivalent to 75% of the maximum range of efficient operations provides this flexibility for a variety of company operations in a given market and that a plot of the maximum project size versus level of capitalization may be developed, as shown in Figure 5.18. The project size we are referring to now is not the maximum project size that the company may bid but the maximum efficient project size that the company should bid. A series of plots, such as the one shown in Figure 5.18, may be used as a quick reference for a company anticipating or planning a change of modus operandi to determine the influence of the change on the profitability of the company for a given market environment (i.e., defined distributions of the estimated project size and the arrival rate of bid opportunities).

To demonstrate and support the above concepts, several experiments were run for a given company operation ($K = 0.002$ and $C = 1.0$ for the backlog of work model). Figures 5.19 and 5.20 present the results of these experiments in graphical form. The optimum level of capitalization for the given operation is equivalent to a mean monthly work completion rate of $120,000 (see Figure 5.10) and this is also the level of capitalization that permits the greatest flexibility in project size that the company may consider when striving to maximize net profits

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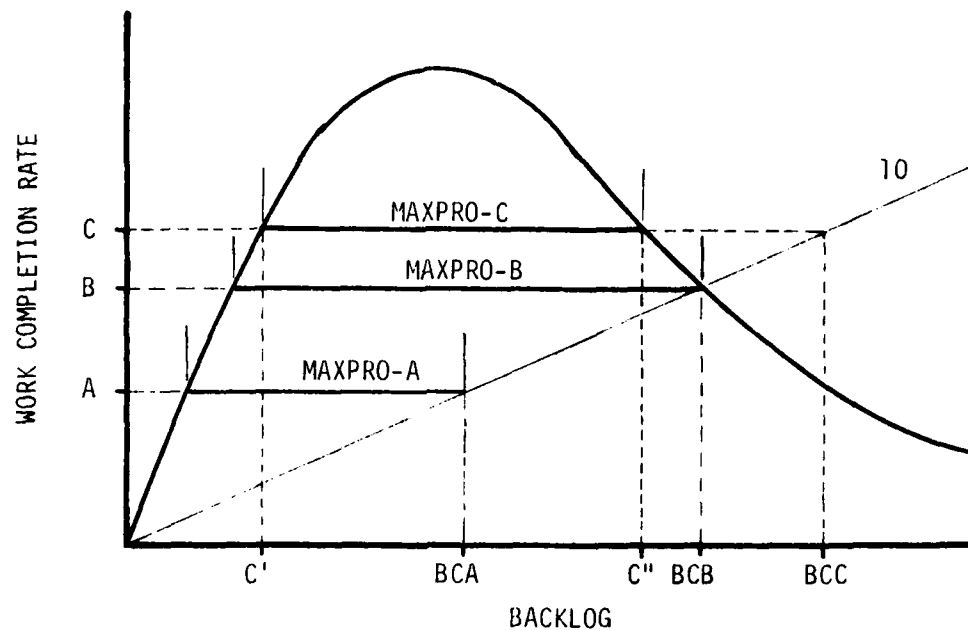
FIGURE 5.17 -- ESTIMATING THE MAXIMUM PROJECT
SIZE
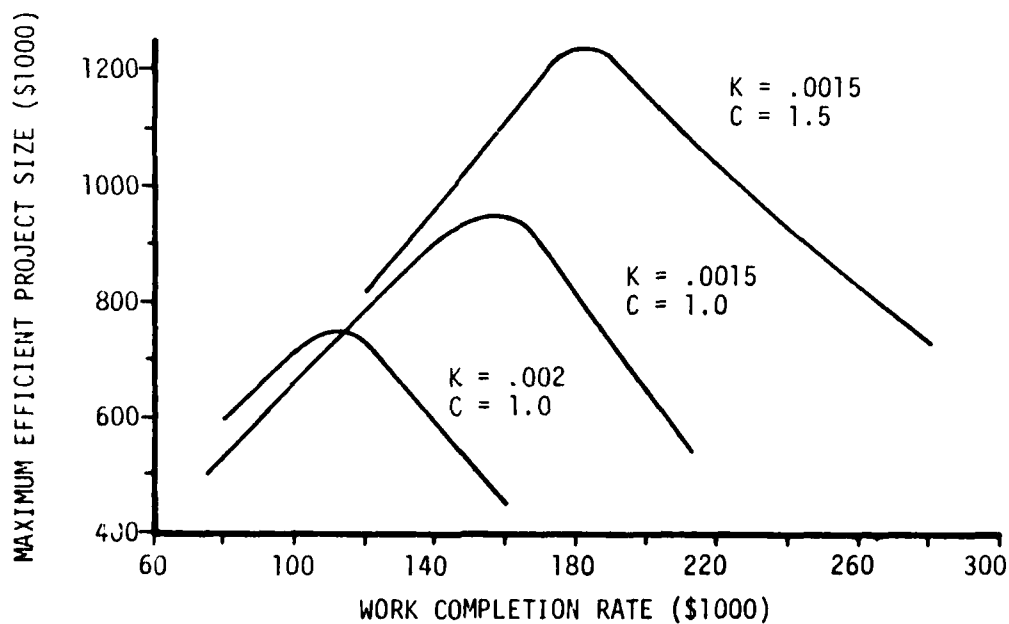
FIGURE 5.18 -- MAXIMUM EFFICIENT PROJECT SIZE ESTIMATED
AT .75 X MAXPRO
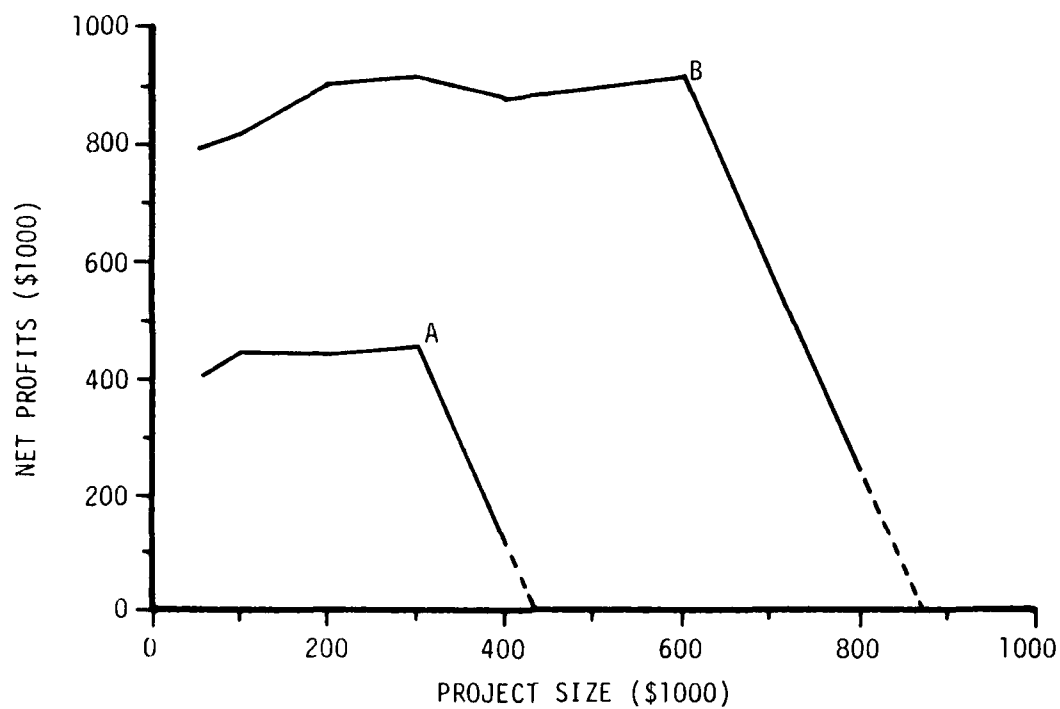
FIGURE 5.19 -- IDENTIFYING THE MAXIMUM EFFICIENT PROJECT
SIZE, W=40 AND W=80
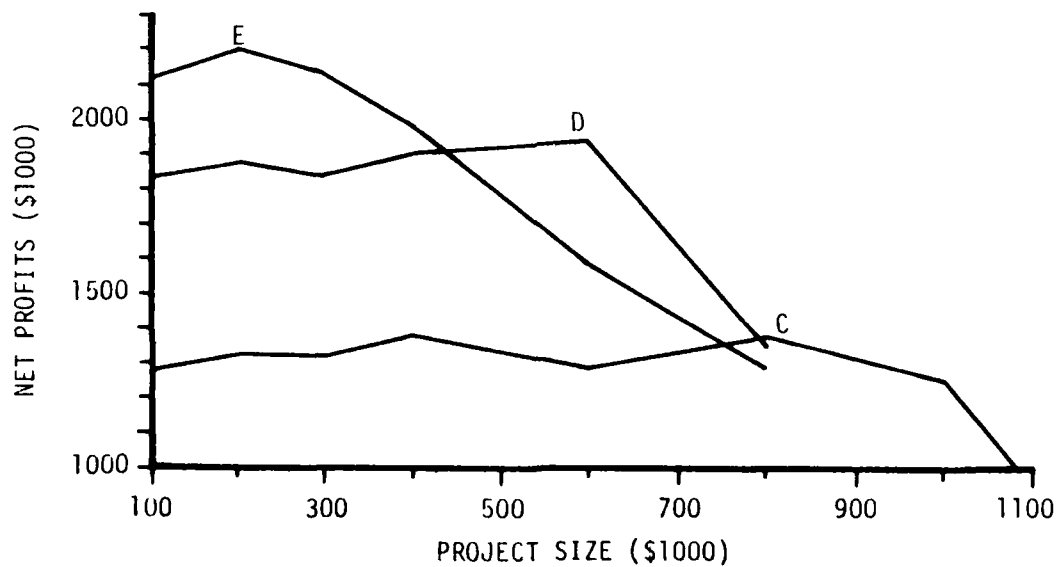
FIGURE 5.20 -- IDENTIFYING THE MAXIMUM EFFICIENT PROJECT
SIZE, W=120, W=160 AND W=200

(breakeven to $800,000). A level of capitalization above or below the optimum level reduces this flexibility as shown in Figure 5.21. The curve shown in this figure is based on the experimental results and is representative of the curves shown in Figure 5.18 that were constructed directly from the prediction backlog of work curves. The ratio of the maximum efficient project size to the range of efficient operations for the experiments is approximately equal to 0.85, whereas it was assumed that this ratio was 0.75 for the curves in Figure 5.18. Because project size was constant for each experiment, this ratio provides only for the flexibility that is required in bidding at the maximum efficient project size due to the backlog of work at the time of award.

The ratio of maximum efficient project size to the range of efficient operations will vary primarily with changes in the market environment. A high ratio may be achieved in a market with sufficient bidding opportunities and a wide range of project sizes since a company may competitively bid projects that permit efficient operations after considering the existing or anticipated backlog of work. This ratio may also be greater than 1.0 if the markup of the low bidder in the market increases as project size increases (i.e., diseconomies of scale are present). For such a condition, the increase in net profits due to a higher markup with larger project sizes may offset the inefficiencies in operations that will occur.

The preliminary studies of the relationship between project size and the backlog of work curve suggest that a maximum efficient project size may be determined for a given company operation in a given market. Due to the simplification involved when modeling an enterprise in a

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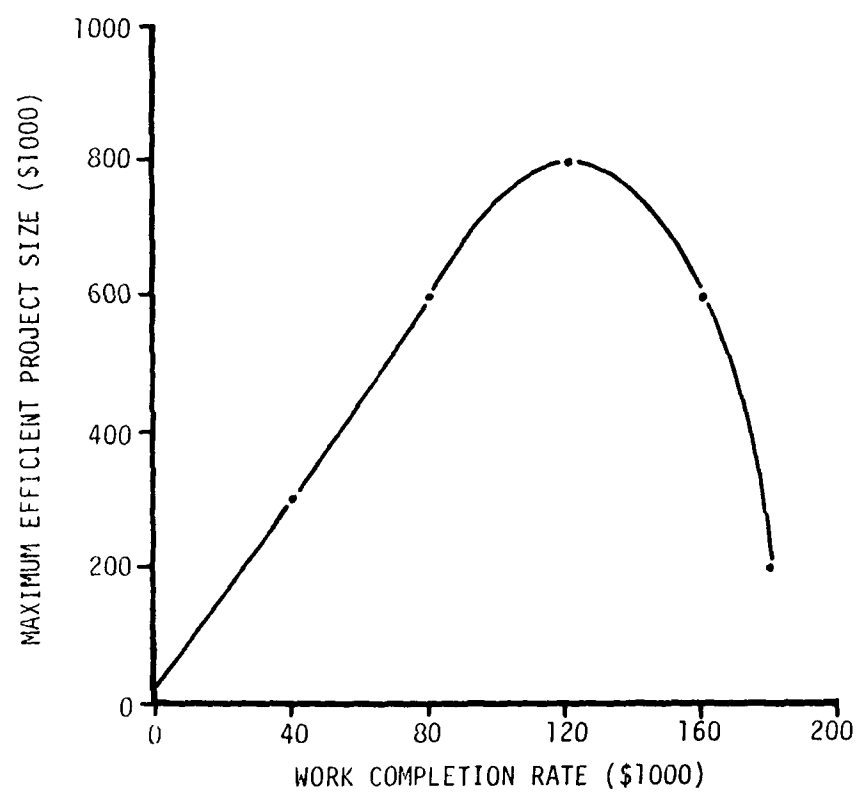
FIGURE 5.21 -- MAXIMUM EFFICIENT PROJECT
SIZE WHEN K=.002 AND C=1.0

market, this maximum efficient project size provides only insight into the potential impact that project size may have on the profitability of the enterprise. The range of backlog for efficient operations for a given company operation and given level of capitalization provides a rough estimate of the maximum efficient project size and this estimate may be adequate when one considers the numerous factors that affect the profitability of a specific project. The findings of these studies suggest, however, that a rule-of-thumb for the maximum project size, such as 50% of the bonding capacity, is inadequate when one considers the relationship between the monthly work completion rate and the back-log of work. It would surely be unwise for a surety to bond a project that accounts for much greater than 50% of a contractor's bonding ca-pacity. But it is equally unwise for a surety to bond a project that accounts for, say, 40% of a contractor's bonding capacity when the maximum efficient project size for the contractor's operation is 30% of his bonding capacity.

5.2.2 Modulus of Project Size

The second phase of studying project size explores the impact of project size on net profits at and around the optimum level of capital-ization. Figures 5.22 and 5.23 present the results of some of these experiments. The remaining results are presented in Appendix F. The above figures show that at the optimum level of capitalization for a given operation net profits increase rapidly from the breakeven project size (in this case $2,000) to some project size where this increase diminishes with additional increases in project size. These figures

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FIGURE 5.23 -- IDENTIFYING THE MODULUS OF
PROJECT SIZE, K=.004 AND C=1.0

FIGURE 5.22 -- IDENTIFYING THE MODULUS OF
PROJECT SIZE, K=.003 AND C=1.0

suggest that one may identify what will be called a modulus of project size for a given operation. It is important to distinguish between the breakeven project size and this modulus of project size. As previously mentioned, expected net profits at the breakeven project size are zero and a contractor may theoretically anticipate that he will neither make or lose money when continuously bidding at this project size. At the modulus of project size, the contractor is bidding profitable work; however, profits decrease rapidly as project size decreases and increase only marginally as project size increases.

The curve shapes in Figures 5.22 and 5.23 for levels of capitalization below the optimum level are similar to the curve for the optimum level of capitalization. Net profits for these undercapitalized operations decrease proportionately with decreases in the level of capitalizaton. The general curve shape changes at levels of capitalization above the optimum level and the modulus of project size increases rapidly with increases in the level of capitalization. Net profits with respect to project size at higher levels of capitalization are very unstable and, at some level of capitalization not shown in these figures, net profits are negative for all project sizes. These experiments also tend to support the concept that it is wise for a contractor to be undercapitalized because net profits are more stable and a wider range of profitable project sizes may be bid.

Figure 5.24 shows a plot of the modulus of project size versus the level of capitalization for 9 different construction operations. With the exception of one operation ($K = 0.004$ and $C = 1.0$), the slope of the relationship between these two variables for all operations was

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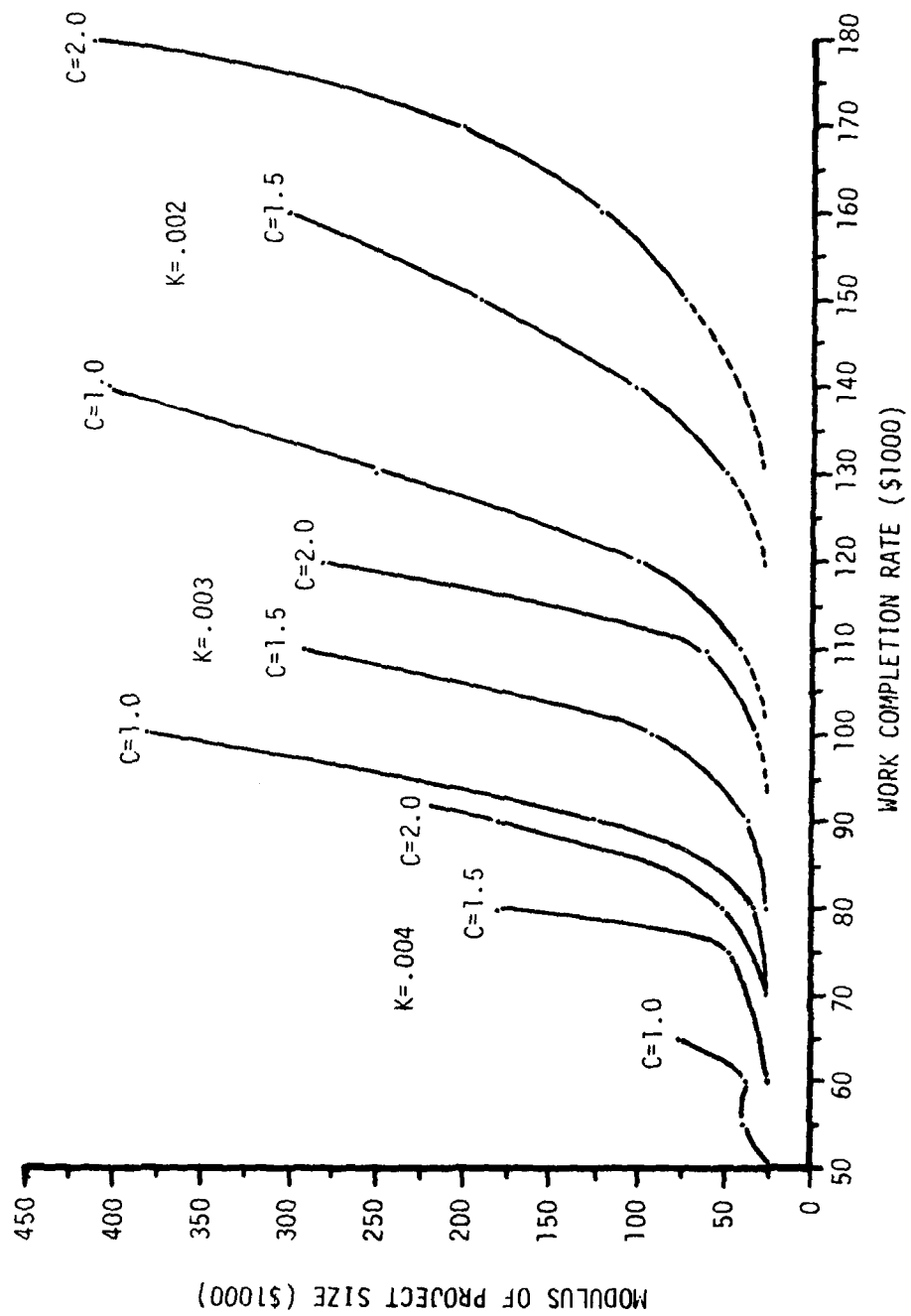
FIGURE 5.24 -- MODULUS OF PROJECT SIZE CURVES

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approximately the same. The relationship varied somewhat at lower levels of capitalization with respect to the optimum level for a given operation; however, it appears that the lowest modulus of project size for this market condition, to include the company's costs of estimating and overhead, is approximately $20,000. The writer was unable to determine a relationship between the modulus of project size and other experimental variables, such as the cost of estimating, the cost of overhead, the parameters K and C in the backlog model, etc. It would be highly desirable to be able to express the relationship between the modulus of project size and the level of capitalization for any operation in equation form for easy use, but until this expression is determined, one must perform an analysis of company and market conditions to determine the modulus of project size.

The determination of the modulus of project size for a given operation is important for several reasons. First, the profitability of an operation may be improved if only projects between the modulus and the maximum efficient project size are bid. Second, for the operations studied in this section, project sizes below the modulus represented approximately 12% of the projects that the company would be permitted to bid if the company's surety set a maximum project size at 50% of the bonding capacity (which is not recommended in the previous section). If a company decides not to bid projects below the modulus, some flexibility is lost in the market place. Third, the modulus could play an important role in the desirability ranking of bid opportunities in portfolio design. As with the maximum efficient project size, the modulus of project size at this stage of development may be used at

best as a general guideline for examining bid opportunities.

5.2.3 Project Size and Net Profits

It would appear to be beneficial for any contractor to under-
stand the impact that project size may have on company net profits.
The concepts presented in the previous two subsections and those of
Larew and Grieve may be combined as shown in Figure 5.25. Five levels
of project size of significant importance are identified: the low
breakeven project size (A), the modulus of project size (B), the opti-
mum project size (C), the maximum efficient project size (D), and the
high breakeven project size (E). An optimum project size may be iden-
tified only for certain market conditions; therefore, the relationship
between net profits and project size may be more or less peaked between
the modulus of project size and the maximum efficient project size, as
shown by the dotted line in Figure 5.25. The high breakeven project
size is found by extending the curves used to determine the maximum
efficient project size as shown in Figure 5.19. It is important to
note that the contractor's surety and banker may never allow the con-
tractor to undertake a project as large as the maximum efficient proj-
ect size or the high breakeven size. The primary intent of examining
and mentioning these projects sizes is to demonstrate the impact of
project size on net profits over the entire range of project sizes that
the contractor may bid without external constraints. While most con-
struction work requires that the contractor is fully bonded, a con-
tractor may pursue unbonded work if he can find it, and the high break-
even project size may be a factor to consider.

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A = Low breakeven project size
B = Modulus of project size
C = Optimum project size
D = Maximum efficient project size
E = High breakeven project size
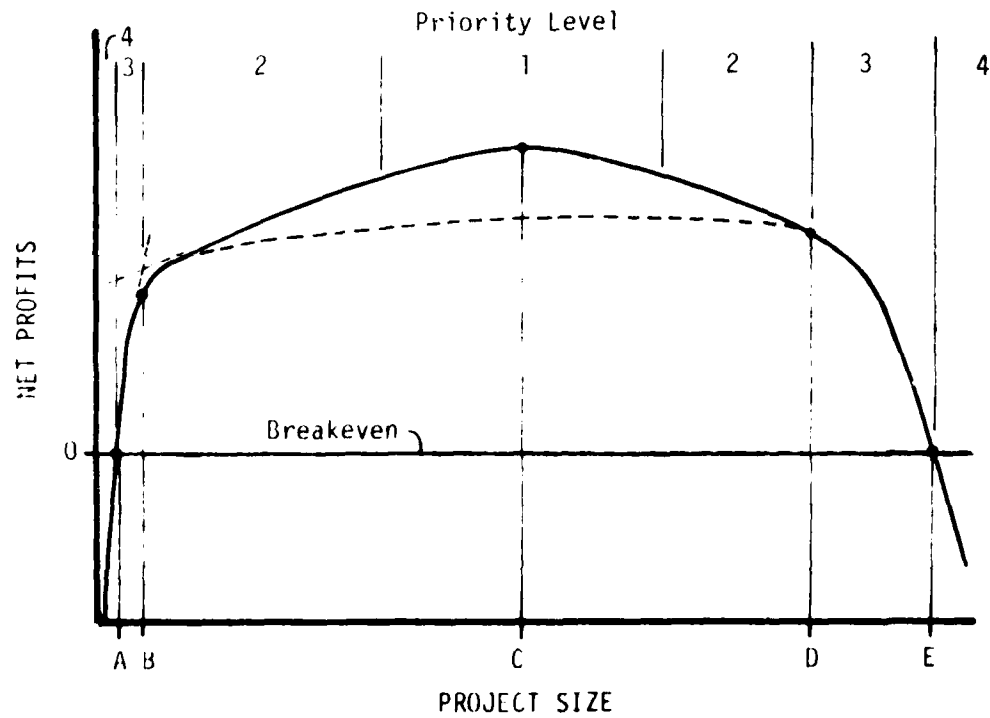
FIGURE 5.25 -- THE IMPACT OF PROJECT SIZE ON NET PROFITS

Once these five levels of project size have been identified, a contractor may establish a rule-of-thumb priority system for ranking the relative desirability of bidding opportunities solely with respect to project size. Four priority levels of project size are suggested in Figure 5.25:

1. Highly desirable,

2. Moderately to highly desirable,

3. Moderately desirable to undesirable,

4. Totally undesirable.

These priority levels are suggested only as an example and the total range of permissible project sizes may be divided into as many priority levels as desired. Individual priority levels may also be weighted in some manner in the evaluation of the total desirability of a bid opportunity. Project size is of course not the only factor to consider in determining which opportunities to competitively bid. Such factors as project location, the quality of design and contract documents, the type of contract, the sophistication of the owner, the Architect/Engineer, the level of competition, etc., provide additional inputs for the analytical or conceptual ranking of bid opportunities. Project size is, however, an important variable to consider in the design and planning of a market strategy aimed at maximizing net profits in a competitively bid environment.

5.3 The Optimum Markup

The previous sections in this chapter discussed the results of experiments in the areas of capitalization and project size. A problem

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beyond the scope of research as stated in Section 4.4 was encountered while trying to determine if the M* markup should be modified with respect to the backlog of work. As a result, this issue is not addressed in this section. This section reports the preliminary results of experiments designed to improve the M* bidding policy by simulating a competitive market with the BACKLOG program.

The distribution of the low bidder's perceived markup versus project size for the first market studied, Market C, is shown in Figure 5.26, and the distribution of the residuals around the fitted line, $M = A + CX^K$, versus project size is shown in Figure 5.27. These two plots were obtained using the MAG program. The reader should note that the low bidder's perceived markup ranges from - 20% to 80% when the contractor's estimated project size is $100,000. The low bidder's perceived markup for this market is expressed by the following equation (the fitted line):

$$M = 0.099439 + 0.660058(X)^{-0.361249} + R(p) \qquad (5.1)$$

The following information describes the R(p) term in the above equation:

> Residuals Mean (M1) = 0.0,
>
> Second Central Moment (M2) = 0.054148,
>
> Alpha3 Table Index (skewness) = 0.20, and
>
> Alpha4 Table Index (kurtosis) = 2.60.

The optimum markup, M*, for this market is expressed by the following equation:
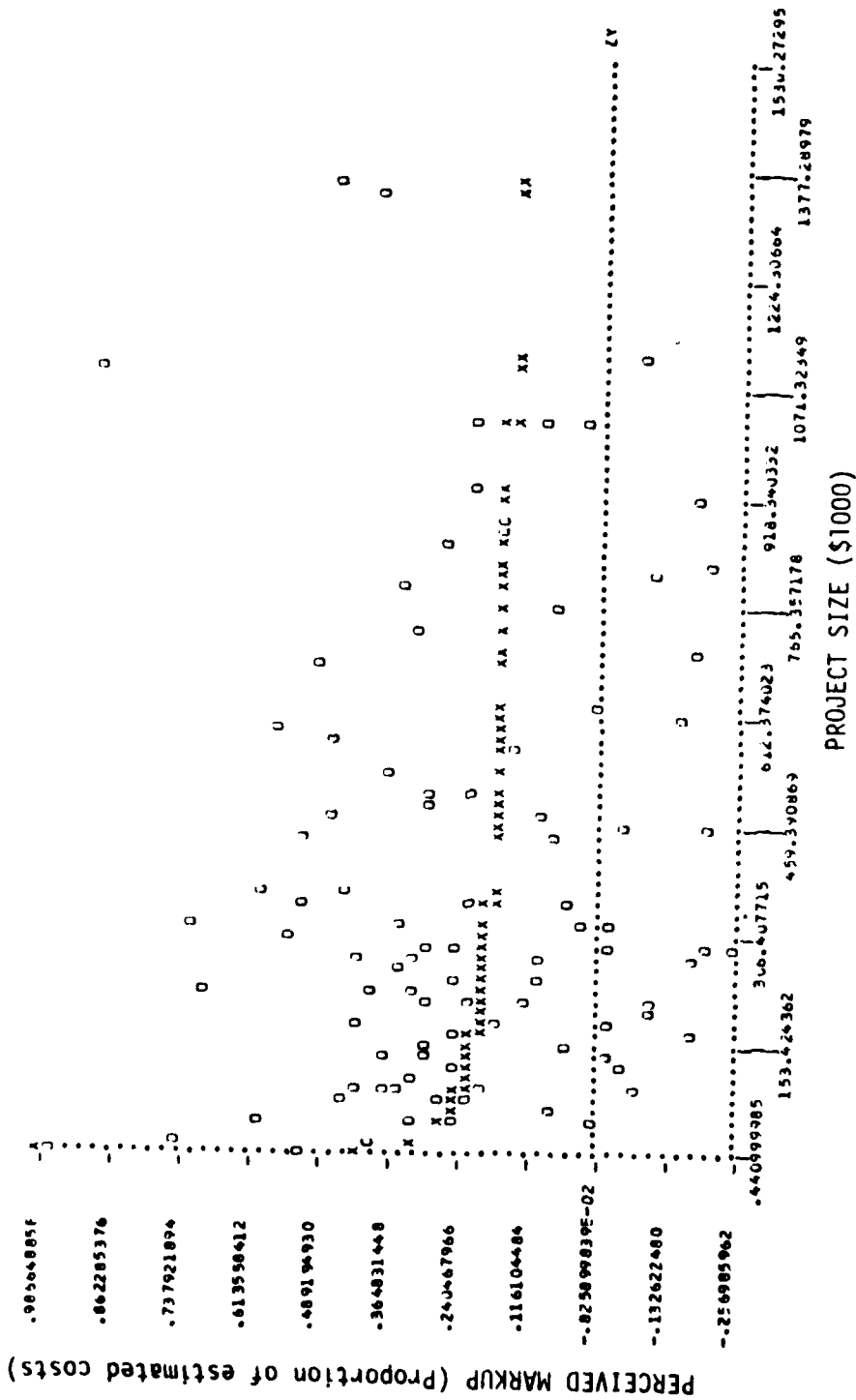
PROJECT SIZE ($1000)

FIGURE 5.26 -- PERCEIVED MARKUP VERSUS PROJECT SIZE FOR MARKET C

PERCEIVED MARKUP (Proportion of estimated costs)
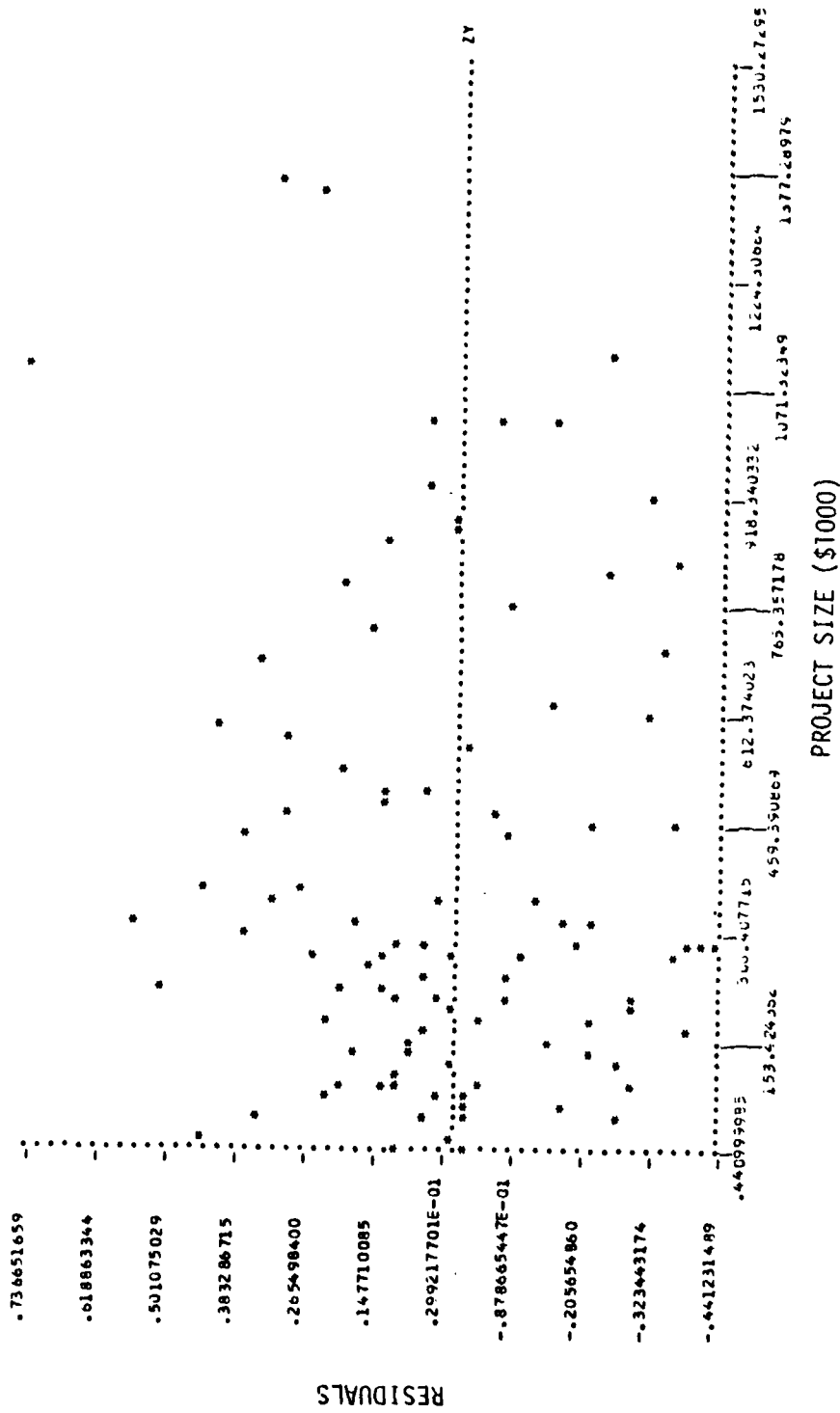
FIGURE 5.27 -- RESIDUALS VERSUS PROJECT SIZE FOR MARKET C

$$M^* = 0.228748 + 0.424572(X)^{-0.316734} \qquad (5.2)$$

For a project size, X, equal to $100,000, the optimum markup found using the above equation is 32.75%. Table 5.1 presents the results of experiments run using the BACKLOG program where the optimum markup is varied by varying the parameter, A, in the M* equation. The first column in this table indicates the sequence in which the experiments were run. In the first set of runs, M* was increased in 9 increments up to M* plus 15%, from 32.75% to 47.75%. Each incremental increase in M* resulted in increased net profits. A second set of experiments were run where M* was increased 20%, 30% and 40%. These experiments showed that profits increased at M* plus 20% and M* plus 30% but decreased significantly for M* plus 40%. A third set of experiments were run to determine the markup at which net profits were maximized according to the BACKLOG program. It was found that net profits for the firm in this market were maximized at a markup equal to 60.75%. It is noted that this markup is 28% higher than the optimum markup found by expectancy pricing, and that net profits at this markup are 79% greater than net profits at the M* markup.

A second set of experiments were run for a more competitive market, Market E. The distribution of the low bidder's perceived markup versus project size for this market is shown in Figure 5.28, and the distribution of the residuals around the fitted line versus project size is shown in Figure 5.29. The low bidder's perceived markup in this market ranges from 15% to 27% when the contractor's estimated project size is

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TABLE 5.1 -- RESULTS FOR MARKET C

Set	Inc.	Markup (%)	#Bid	#Won	Bid/Get Ratio	Net Profits ($1000's)
1	M*	32.75	252	85	2.9647	1390
1	1%	33.75	263	85	3.0904	1449
1	2%	34.75	283	85	3.3294	1500
1	3%	35.75	285	85	3.3529	1566
1	4%	36.75	292	85	3.4353	1628
1	5%	37.75	320	85	3.7647	1673
1	7%	39.75	365	85	4.2941	1771
1	9%	41.75	407	85	4.7882	1871
1	12%	44.75	476	85	5.6000	2017
1	15%	47.75	581	85	6.8353	2132
2	20%	52.75	849	85	9.9880	2246
3	22%	54.75	913	85	10.7412	2328
3	24%	56.75	1012	85	11.9059	2381
3	26%	58.75	1114	85	13.1059	2431
3	28%	60.75	1271	85	14.9529	2486
2	30%	62.75	1519	85	17.8706	2415
3	32%	64.75	1826	85	21.4823	2405
3	36%	68.75	2132	66	32.3030	2311
2	40%	72.75	2132	37	57.6200	679
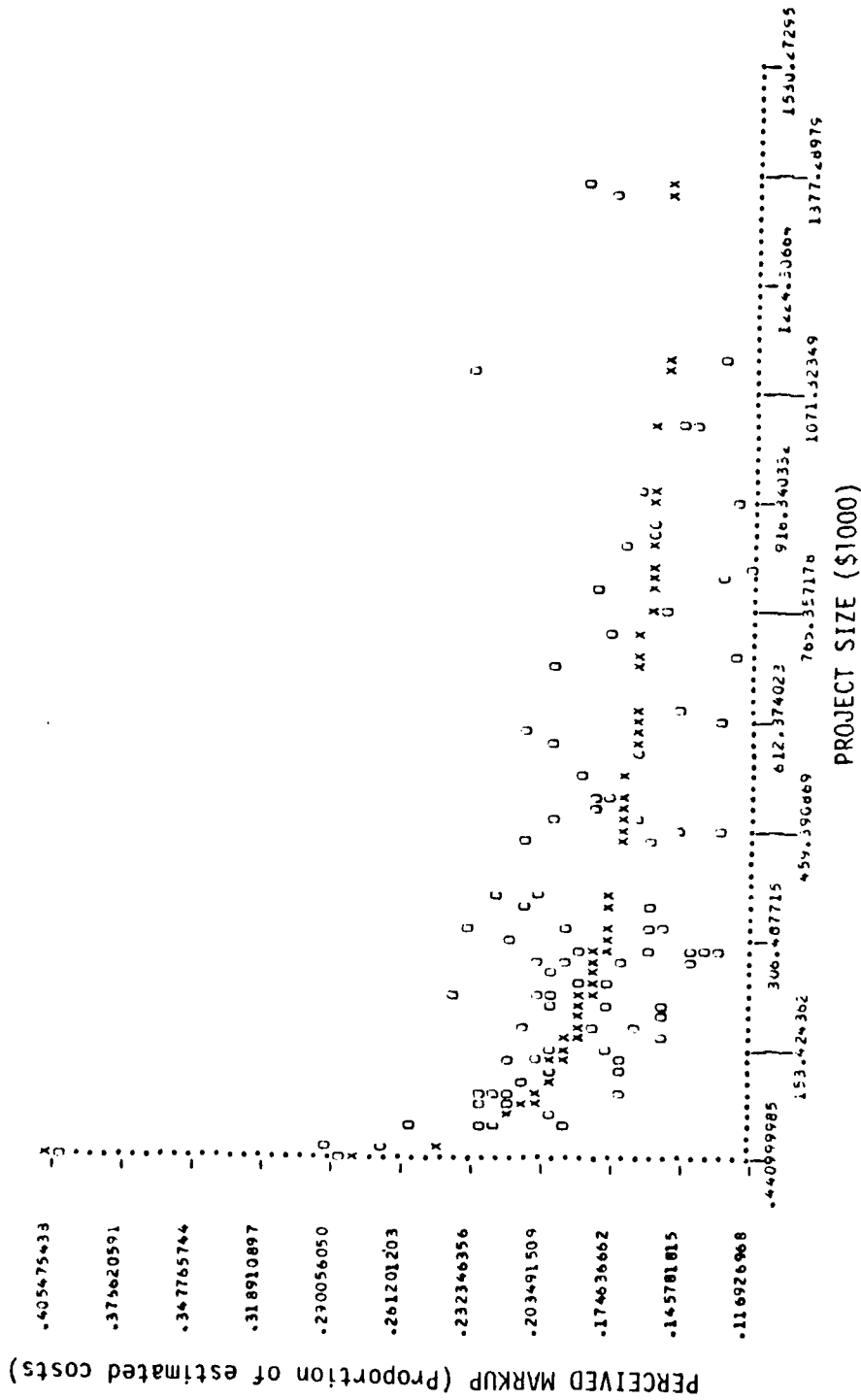
FIGURE 5.28 -- PERCEIVED MARKUP VERSUS PROJECT SIZE FOR MARKET E
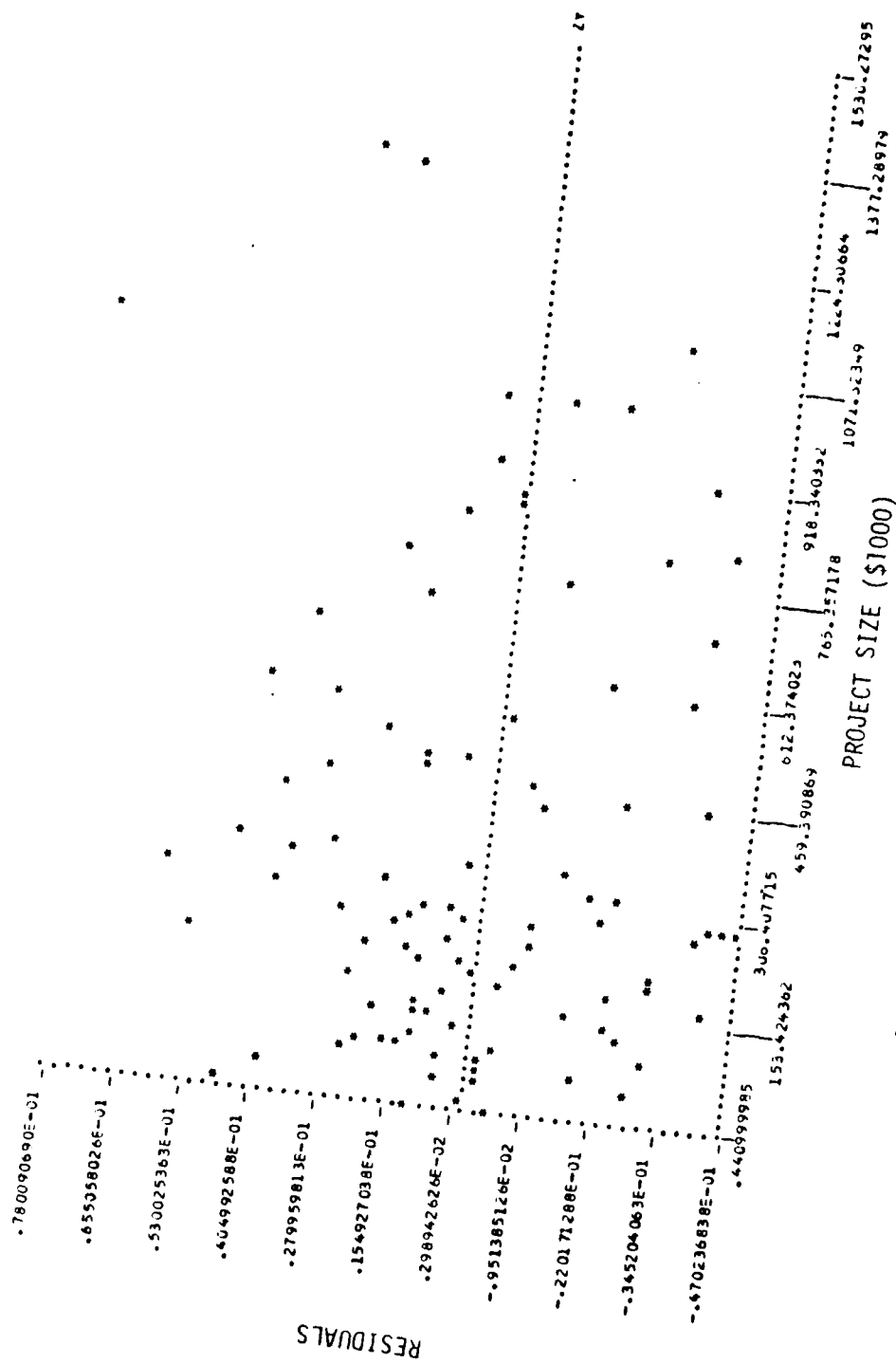
FIGURE 5.29 -- RESIDUALS VERSUS PROJECT SIZE FOR MARKET E

$100,000. The low bidder's perceived markup for this market is expressed by the following equation:

$$M = 0.049009 + 0.313544(X)^{-0.156712} + R(p) \qquad (5.3)$$

The following information describes the $R(p)$ term in the above equation:

Residuals Mean (M1) = 0.0,

Second Central Moment (M2) = 0.000619,

Alpha3 Table Index (skewness) = 0.20, and

Alpha4 Table Index (kurtosis) = 2.60

The optimum markup, M*, for this market is expressed by the following equation:

$$M* = 0.038066 + 0.304776(X)^{-0.175566} \qquad (5.4)$$

For a project size, X, equal to $100,000, the optimum markup found using the above equation is 17.38%. Table 5.2 presents the simulation results for this market with the cost of estimating function:

$$C_e = 0.15(X)^{0.375} \qquad (5.5)$$

Table 5.3 presents the simulation results for this market with the cost of estimating function:

$$C_e = 0.30(X)^{0.375} \qquad (5.6)$$

TABLE 5.2 -- RESULTS FOR MARKET E, $C_e = .15(x)^{.375}$

Increment (%)	Markup (%)	# Bid	# Won	Bid/Get Ratio	Net Profits ($1000's)
M*	17.38	96	85	1.1294	477
+.5%	17.88	101	85	1.1882	507
+1.0%	18.38	107	85	1.2588	536
+2.0%	19.38	135	85	1.5882	580
+3.2%	20.58	212	85	2.4941	597
+3.4%	20.78	213	85	2.5059	610
+3.6%	20.98	223	85	2.6235	615
+3.7%	21.08	243	85	2.8588	605
+3.8%	21.18	250	85	2.9412	606
+4.0%	21.38	272	85	3.2000	601
+4.2%	21.58	285	85	3.3529	603
+4.4%	21.78	322	85	3.7882	586
+6.0%	23.38	866	85	10.188	236

TABLE 5.3 -- RESULTS FOR MARKET E, $C_e = .30(x)^{.375}$

Increment (%)	Markup (%)	# Bid	# Won	Bid/Get Ratio	Net Profits ($1000's)
M*	17.38	96	85	1.1294	389
+.5%	17.88	101	85	1.1882	415
+1.0%	18.38	107	85	1.2588	439
+1.6%	18.98	119	85	1.4000	459
+1.8%	19.18	127	85	1.4941	459
+2.0%	19.38	135	85	1.5882	450
+2.2%	19.58	150	85	1.7647	448
+2.4%	19.78	165	85	1.9412	436
+2.5%	19.88	180	85	2.1176	418
+2.6%	19.98	183	85	2.1529	419
+2.8%	20.18	193	85	2.2706	416
+3.0%	20.38	210	85	2.4706	401
+4.0%	21.38	272	85	3.2000	364
+5.0%	22.38	429	85	5.0471	168

The markup which maximizes net profits for the firm is not the same for the above sets of experiments, but, according to expectancy pricing, only one markup will maximize net profits for a given project size. The optimum markup for the first set of experiments is 20.98% (M* plus 3.6%) while the optimum markup for the second set of experiments is 19.18% (M* plus 1.8%). Net profits at these markups are 29% and 18% higher, respectively, than net profits bidding at M*.

The results of the above experiments show that the optimum markup found by any expectancy pricing bidding strategy is not always the markup that maximizes net profits for a firm. A model was developed that maximizes net profits for a given production capacity (i.e. a known monthly mean work completion rate). (16) (It is recommended that the reader review Appendix A if he/she is unfamiliar with expectancy pricing and the M* bidding strategy.) The development of this new model is outlined in the following paragraphs.

If it is assumed that true costs equal estimated costs, net profits for a project may be considered to equal the markup applied to the cost estimate minus the costs of overhead. This relationship for the M* bidding policy is shown in the following equation:

$$\pi = (A + CX^K + R(p)) - C_{01} - \frac{C_{02}}{(1 - p)} \qquad (5.7)$$

where: π = Net profits,

$A + CX^K + R(p)$ = Markup,

C_{01} = Cost of overhead function for any overhead that does not vary with the bid/get ratio, and

C_{02} = Cost of overhead function for any overhead that varies with the bid/get ratio.

C_{02} is equivalent to the costs of estimating for experiments run in this section since it is known that these costs vary with the bid/get ratio. It is noted that the M* bidding strategy is the only bidding strategy in the construction literature that addresses these variable costs.

According to the expectancy pricing theory, expected net profits are found by the following equation:

$$E(\pi) = (A + CX^K + R(p))(1 - p) - C_{01}(1 - p) - C_{02} \qquad (5.8)$$

where: $E(\pi)$ = Expected net profits, and

$(1 - p)$ = Probability of winning a project associated with the above markup.

The optimum markup (M*) may be found by setting the derivative of the equation equal to zero, solving for p* (the optimum value of p) and then finding the markup that is associated with p*. While this markup maximizes the average net profits per bid submitted, it is not the markup that maximizes net profits for the firm (see the last column in Tables 5.1, 5.2, and 5.3).

The experiments presented above suggest that a contractor should not strive to maximize expected net profits using Eq. 5.8. Instead, the contractor should strive to maximize net profits using Eq. 5.7. Taking the derivative of Eq. 5.7 with respect to p and setting it equal

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to zero we find that:

$$\frac{d}{dp}(R(p)) = \frac{C_{02}}{(1 - p)^2} \qquad (5.9)$$

where: $\frac{d}{dp}(R(p))$ = The derivative of the probability density function describing the distribution of the low bidder's perceived markup.

The expression, $\frac{d}{dp}(R(p))$, is equivalent to $\frac{1}{f(R(p))}$ (14:44), therefore, the above equation may be expressed as:

$$\frac{1}{f(R(p))} = \frac{C_{02}}{(1 - p)^2} \qquad (5.10)$$

Values for $f(R(p))$ for the two markets studied in this section are presented in Tables 5.4 and 5.5. Table 5.6 shows the results of the experiments for market C and the values of $\frac{1}{f(R(p))}$ and $\frac{C_{02}}{(1 - p)^2}$ for each level of markup.* It is noted that the optimum markup, 60.75%, found by simulation is the markup that approximately satisfies the above equation. (See Appendix F for a plot of $\frac{1}{f(R(p))}$ and $\frac{C_{02}}{(1 - p)^2}$ for markets C and E).

Tables 5.7 and 5.8 show the results of the experiments for market E and the values of $\frac{1}{f(R(p))}$ and $\frac{C_{02}}{(1 - p)^2}$. While the simulation results indicate that the optimum markup is 20.98% when $C_{02} = 0.15(X)^{.375}$, the above expression is approximately satisfied at a markup of 21.18%. When $C_{02} = 0.30(X)^{.375}$, the above expression is approximately satisfied at a markup of 19.78% while simulation results indicate that the

*C_{02} is expressed in dollars in the BACKLOG program and must be divided by project size (100) to obtain the values in Tables 5.6, 5.7 and 5.8.

TABLE 5.4 -- P AND f(R(p)) FOR MARKET C

p	f(R(p))	p	f(R(p))	p	f(R(p))
.01	.159935	.34	1.59399	.67	1.38368
.02	.283313	.35	1.60182	.68	1.36420
.03	.391127	.36	1.60856	.69	1.34397
.04	.487913	.37	1.61422	.70	1.32297
.05	.575976	.38	1.61885	.71	1.30120
.06	.656765	.39	1.62247	.72	1.27864
.07	.731295	.40	1.62510	.73	1.25528
.08	.800328	.41	1.62678	.74	1.23110
.09	.864459	.42	1.62752	.75	1.20608
.10	.924171	.43	1.62735	.76	1.18020
.11	.979864	.44	1.62628	.77	1.15345
.12	1.03188	.45	1.62434	.78	1.12578
.13	1.08049	.46	1.62155	.79	1.09717
.14	1.12597	.47	1.61791	.80	1.06758
.15	1.16852	.48	1.61344	.81	1.03698
.16	1.20834	.49	1.60817	.82	1.00531
.17	1.24560	.50	1.60209	.83	.972530
.18	1.28046	.51	1.59523	.84	.938572
.19	1.31305	.52	1.58758	.85	.903367
.20	1.34350	.53	1.57917	.86	.866835
.21	1.37192	.54	1.57000	.87	.828879
.22	1.39842	.55	1.56008	.88	.789385
.23	1.42308	.56	1.54941	.89	.748215
.24	1.44600	.57	1.52585	.90	.705204
.25	1.46726	.58	1.52585	.91	.660146
.26	1.48692	.59	1.51297	.92	.612778
.27	1.50505	.60	1.49936	.93	.562765
.28	1.52173	.61	1.48503	.94	.509563
.29	1.53699	.62	1.46996	.95	.452810
.30	1.55091	.63	1.45417	.96	.391303
.31	1.56352	.64	1.43765	.97	.323626
.32	1.57488	.65	1.42040	.98	.247011
.33	1.58502	.66	1.40241		

TABLE 5.5 -- P AND f(R(p)) FOR MARKET E

p	f(R(p))	p	f(R(p))	p	f(R(p))
.01	1.49575	.34	14.9074	.67	12.9405
.02	2.64961	.35	14.9806	.68	12.7583
.03	3.65791	.36	15.0436	.69	12.5691
.04	4.56308	.37	15.0966	.70	12.3727
.05	5.38667	.38	15.1399	.71	12.1691
.06	6.14222	.39	15.1737	.72	11.9581
.07	6.83925	.40	15.1983	.73	11.7396
.08	7.48485	.41	15.2140	.74	11.5135
.09	8.08462	.42	15.2210	.75	11.2795
.10	8.64307	.43	15.2193	.76	11.0376
.11	9.16390	.44	15.2094	.77	10.7873
.12	9.65034	.45	15.1912	.78	10.5285
.13	10.1050	.46	15.1651	.79	10.2610
.14	10.5303	.47	15.1311	.80	9.98428
.15	10.9283	.48	15.0893	.81	9.69807
.16	11.3007	.49	15.0400	.82	9.40191
.17	11.6492	.50	14.9831	.83	9.09533
.18	11.9752	.51	14.9189	.84	8.77775
.19	12.2800	.52	14.8475	.85	8.44851
.20	12.5648	.53	14.7688	.86	8.10685
.21	12.8306	.54	14.6830	.87	7.75187
.22	13.0784	.55	14.5902	.88	7.38251
.23	13.3090	.56	14.4904	.89	6.99749
.24	13.5234	.57	14.3837	.90	6.59524
.25	13.7221	.58	14.2701	.91	6.17384
.26	13.9060	.59	14.1497	.92	5.73085
.27	14.0756	.60	14.0224	.93	5.26311
.28	14.2315	.61	13.8883	.94	4.76639
.29	14.3743	.62	13.7475	.95	4.23479
.30	14.5045	.63	13.5998	.96	3.65956
.31	14.6224	.64	13.4453	.97	3.02662
.32	14.7286	.65	13.2839	.98	2.31011
.33	14.8235	.66	13.1157		

TABLE 5.6 -- ANALYSIS FOR MARKET C

Incr.	(1-p)	p	Net Profits	$\frac{1}{f(R(p))}$	$\frac{C_{02}}{(1-p)^2}$
M*	.3373	.6627	1390	.7131	.0741
+1.0%	.3232	.6768	1449	.7330	.0808
+2.0%	.3004	.6996	1500	.7559	.0935
+3.0%	.2982	.7018	1566	.7559	.0948
+4.0%	.2911	.7089	1628	.7685	.0995
+5.0%	.2656	.7344	1673	.7966	.1196
+7.0%	.2329	.7671	1771	.8670	.1555
+9.0%	.2088	.7912	1871	.9114	.1934
+12.0%	.1786	.8214	2017	.9947	.2645
+15.0%	.1463	.8537	2132	1.1070	.3941
+20.0%	.1001	.8999	2246	1.4180	.8415
+22.0%	.0931	.9069	2328	1.4858	.9732
+24.0%	.0840	.9160	2381	1.5851	1.1957
+26.0%	.0763	.9237	2431	1.6855	1.4488
+28.0%	.0669	.9331	2486	1.8348	1.8860
+30.0%	.0560	.9440	2415	2.0616	2.6938
+32.0%	.0466	.9534	2405	2.3282	3.8927
+36.0%	.0310	.9690	2311	3.0387	8.8019
+40.0%	.0174	.9826	679	4.0484	28.007

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TABLE 5.7 -- ANALYSIS FOR MARKET E, $C_{02}=.15(x)^{.375}$

Incr.	(1-p)	p	Net Profits	$\dfrac{1}{f(R(p))}$	$\dfrac{C_{02}}{(1-p)^2}$
M*	.8854	.1146	477	.1064	.0108
+.5%	.8416	.1584	507	.0885	.0120
+1.0%	.7944	.2056	536	.0795	.0134
+2.0%	.6296	.3704	580	.0662	.0213
+3.2%	.4009	.5991	597	.0712	.0514
+3.4%	.3991	.6009	610	.0713	.0527
+3.6%	.3812	.6188	615	.0726	.0578
+3.7%	.3498	.6502	605	.0753	.0689
+3.8%	.3400	.6600	606	.0762	.0730
+4.0%	.3125	.6875	601	.0793	.0867
+4.2%	.2982	.7018	603	.0810	.0944
+4.4%	.2640	.7360	586	.0862	.1210
+6.0%	.0982	.9018	236	.1537	.8786

TABLE 5.8 -- ANALYSIS FOR MARKET E, $C_{02} = .30(x)^{.375}$

Incr.	(1-p)	p	Net Profits	$\frac{1}{f(R(p))}$	$\frac{C_{02}}{(1-p)^2}$
M*	.8854	.1146	389	.1064	.0215
+.5%	.8416	.1584	415	.0885	.0239
+1.0%	.7944	.2056	439	.0795	.0268
+1.6%	.7143	.2857	459	.0699	.0331
+1.8%	16693	.3307	459	.0675	.0375
+2.0%	.6296	.3704	450	.0662	.0426
+2.2%	.5667	.4333	448	.0657	.0523
+2.4%	.5151	.4849	436	.0664	10636
+2.5%	.4722	.5278	418	.0676	.0757
+2.6%	.4645	.5355	419	.0679	.0780
+2.8%	.4404	.5596	416	.0690	.0871
+3.0%	.4048	.5952	401	.0707	.1029
+4.0%	.3125	.6875	364	.0793	.1734
+5.0%	.1981	.8019	168	.1537	1.753

optimum markup is 19.18%.

Prior to the above experiments, it was suggested that the key
for success in a competitively bid market include:

1. VARIABLE COSTS -- Costs that vary with the bid/get ratio,

2. MARKET PRICE -- Project size and the distribution of residual
markups around a fitted line describing the relationship between the
low bidder's perceived markup and the contractor's estimated project
size,

3. MARKETING CAPACITY -- The arrival rate of bidding opportunities
known by the contractor,

4. PRODUCTION CAPACITY -- The relationship between the mean month-
ly work completion rate and the backlog of work for the enterprise, and

5. ESTIMATING CAPACITY -- The ability of the contractor to hire
qualified estimators such that an increase in the bid/get ratio can be
handled. (16)

The results in this section indicate that the above are definitely the
key factors that must be considered in the development of a competitive
bidding strategy. It is noted that Eq. 5.10 does not consider econo-
mies or diseconomies of scale that may be associated with the costs of
securing additional bidding opportunities (i.e., it is implicitly
assumed that these costs are linear). It has been suggested that these
marketing costs may be non-linear and that Eq. 5.10 can be further gen-
eralized for this condition.

The experiments and models developed in this section indicate that
expectancy pricing theory is invalid, and that a contractor will maxi-
mize net profits in a competitively bid market when marketing costs are

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linear by satisfying the relationship:

$$\frac{1}{f(R(p))} = \frac{C_{02}}{(1 - p)^2}$$

5.4 Summary

This chapter has reported and discussed the writer's major experimental results and studies. In summary, it was found that:

1. An optimum level of capitalization can be identified for a given operation using the backlog model,

2. The backlog model and level of capitalization should be considered in the establishment of a firm's bonding capacity,

3. The level of capitalization self-adjusts to the unknown optimum level of capitalization if a contractor is unaware of the relationship between W and U,

4. The backlog model can be used to determine the optimum mix of operating and working capital for a given operation,

5. A maximum efficient project size can be identified for a given operation,

6. A modulus of project size can be identified for a given operation, and

7. Expectancy pricing theory is invalid. The optimum markup for a given market condition can be found by the variable costs methodology.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS FOR

FUTURE RESEARCH

The first section in this chapter summarizes the writer's conclu-
sions concerning the results of experiments and studies reported in
Chapter 5. This discussion is followed by recommendations for future
research that have evolved from the studies and findings in this thesis.

6.1 Conclusions

The scope of the first area of research in this thesis was out-
lined in Section 4.4 by the following questions:

> Can the backlog model be used to explore organiza-
> tional financial design? Does an optimum level of
> capitalization exist for an operation with a pre-
> determined bonding capacity? Does an optimum level
> of capitalization exist when bonding capacity
> varies with the level of capitalization? Can the
> model be used to determine how much working capital
> should be allocated to field operations?

The results of the experiments and studies reported in Section 5.1 lead

this writer to conclude that the backlog model is valid (useful) for

studying the above issues. Experiments showed that an optimum level of

capitalization can be identified using the model for any given opera-

tion and set of constraints. The descriptive power of the model was

shown by the identification of a self-adjusting principle. The appli-

cation of this principle to the study of an actual company operation provided valuable insight into the relationship between the mean monthly work completion rate and the backlog of work and suggested that the principle can be a powerful tool in describing the impact of changes in the above relationship, reasons for low profits and apparent inefficiencies in operations, etc. The issue of financial design was only briefly discussed; however, the model holds great potential for determining how working capital should be allocated to field operations, how working capital should be allocated to separate classes of work for a multi-operation firm, etc.

The scope of the second area of research was outlined by the following questions:

> Can the model be used to explore the impact of project size on company net profits? Does a maximum project size exist for a given operation and level of capitalization?

Based upon the results presented in Section 5.2, the writer concludes that the model can be used to answer the above questions. A maximum efficient project size was identified for a given operation based primarily on the range of backlog over which operations were efficient. The work completion rate in this range is not impacted by the backlog model (Eq. 2.1) and is determined solely by the work completion rate function (Eq. 3.1). While this maximum efficient project size would typically be greater than the maximum project size allowed by a contractor's banker or surety, it does provide additional insight into the impact of project size on net profits and on a firm's business strategy.

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A second project size, the modulus of project size, was identified for a variety of operations described by the backlog model. The modulus of project size takes on significant importance if a firm's primary objective is to maximize net profits. At project sizes lower than the modulus, net profits decrease rapidly to the low breakeven project size. At project sizes greater than the modulus, net profits increase only marginally with increases in project size. It would appear that the identification of the modulus of project size could be an important factor in the development of a business strategy.

The writer's original intent in the third area of research was to attempt to answer the following questions:

> Should the optimum markup found by expectancy
> pricing be modified with respect to the backlog
> of work to maximize company net profits? If so,
> when and to what degree should the markup be
> modified?

The BACKLOG program was written in fact primarily to address the above issues. Unfortunately, these questions were entertained only briefly during the course of research. The results of the preliminary experiments designed to seek answers to the above questions raised an issue beyond the original scope of this thesis:

> Can the optimum markup found by expectancy
> pricing be improved by simulating a competitive
> bidding environment with production and capital
> constraints defined by the backlog model? If
> so, why?

The writer concludes that pricing with the variable costs methodology outlined in Section 5.3 produces greater profits than expectancy pricing. This conclusion is also supported by independent studies performed by Larew that are not presented in this thesis. The development of the

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variable costs methodology was possible for two reasons. First, the M*
bidding policy accounted for variable costs (costs of estimating) in
the net profits equation (Eq. 5.7). The M* policy is the only bidding
strategy in the construction literature that addresses these variable
costs. Second. the backlog model introduced production utilization and
capacity in the simulation of a competitive bidding environment.

The writer does not doubt that Eq. 5.10 represents a generalized
condition where variable marketing costs are implicitly assumed to be
linear; however, this equation does represent the initial step in a
new direction for analytical pricing in competitively bid markets.

6.2 Recommendations for Future Research

The writer offers the following recommendations concerning future
research:

1. The variable costs methodology as presented in Section 5.3
needs to be further refined and tested. The writer believes that each
of the key factors listed in Section 5.3 must be incorporated into a
general model such that an optimum markup is identified within the con-
straints of each factor. For example, Table 5.1 shows that the con-
tractor should bid 1271 projects in 5 years at M* plus 28% to maximize
net profits in the given market. If only 600 bidding opportunities had
been available, would the contractor have maximized net profits bidding
at M* plus 15%?

Most construction firms have a limited amount of capital available for meeting payroll expenses, purchasing materials, financing day-to-day operations, etc. Each of the key factors mentioned above are supported by the same capital base: increased levels of estimating require more capital, improved marketing techniques require capital, field operations require capital, etc. The writer believes that an optimum business strategy must balance these expenses such that net profits for the firm are maximized. Linear programming may prove to be a useful tool for examining the financial constraints of the key business factors.

2. The writer strongly believes that the time domain and its impact on company design should be studied. Figure 6.1 provides an example of where time may impact the decision making process and direction of a firm. This figure shows a predicted slump in a firm's backlog in the near future. The contractor is faced with questions, such as:

> Should the production capacity for the firm be permanently lowered to, say, level A to minimize the negative impacts of a highly variable backlog, e.g., hiring and firing of personnel, short term equipment rentals, idle equipment during slumps, etc.?

> Should the optimum markup be lowered to obtain a sufficient volume of work at, say, level B?

> Should top executives temporarily lower field capitalization at, say, time C and invest in other business ventures?

The writer believes that the time domain should be studied using the backlog model and adapted manufacturing techniques, such as production smoothing.

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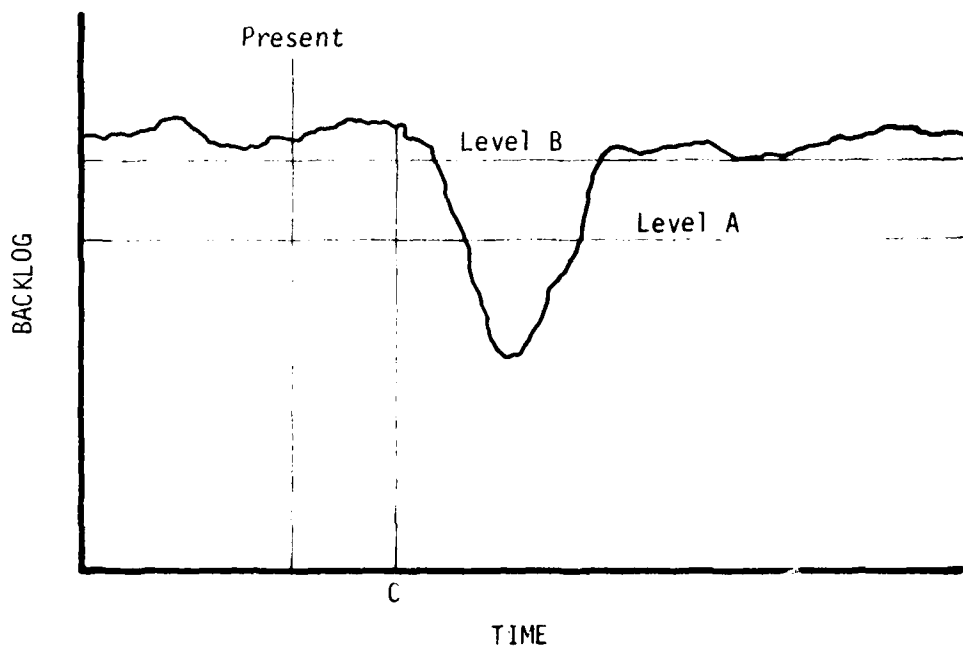
FIGURE 6.1 -- BACKLOG VERSUS TIME

3. The backlog model appears to be a powerful tool that may be used to examine a wide variety of issues facing the construction firm decision maker. The writer believes that the model needs to be further refined and tested in the field before an accurate evaluation of the model's potential can be made. Basic definitional problems must be solved, and each variable and parameter in the backlog model (Eq. 2.1) and the work completion rate function (Eq. 3.1) should be studied.

4. The issue of the impact of project size on net profits needs to be further studied. Statistical relationships between the five levels of project size outlined in Section 5.2.3 and variables, such as the costs of estimating and overhead, should be developed. These milestone project sizes could then be easily determined for any given operation.

5. Using the variable costs methodology, it should be determined if the practice of modifying the optimum markup with respect to the backlog of work is self-defeating. Insight gained from the research in this thesis leads the writer to believe that it is self-defeating to increase the markup at high levels of backlog; however, several experiments and the self-adjusting principle lead the writer to believe that the markup should be decreased when the backlog of work decreases to a point where operations become inefficient.

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APPENDIX A

THE M* AND M** BIDDING STRATEGIES

The BACKLOG computer program compares two bidding strategies over
a specified period of time while constraining company operations with
the backlog of work model. Figure 4.1 showed that the M* bidding strate-
gy implicitly assumes that the company operates with a constant work
completion rate. The M** bidding strategy is a modification of the M*
strategy and incorporates the constraints of the backlog of work model,
as shown in Figure 4.2, in the general bidding strategy. This appendix
presents a brief discussion of these bidding strategies. The works of
Larew (13), Fantozzi (8), Ludolph (18), Frost (9), Grieve (10) and
Ricer (23) should be referenced for a thorough study of the development,
refinement and applicability of the M* bidding strategy.

A.1 The M* Bidding Strategy*

Pricing studies performed by Larew (14) indicate that 1) markups
of competitors may be expressed as a function of project size, 2) mark-
ups may or may not be independent of project size, and 3) economies or
diseconomies of scale may exist in a competitively bid market. Based
_____
*The format and some comments in this section were taken from Fan-
tozzi, Chapter 2, Section 2.3. The text is changed only for clarifica-
tion and adaptive style.

on these findings, Larew developed an equation for predicting the response variable, markup, as a function of the independent variable, estimated cost (or estimated project size). The equation is:

$$M = A + CX^K \qquad (A.1)$$

where, M = The markup as a percentage or proportion of the estimated cost,

       X = The estimated cost,

       A = An estimate of the constant percentage added to any project irrespective of project size,

       C = An estimate of the constant of proportionality, and

       K = An estimate of the economy of scale coefficient.

Larew found that markups tend to decrease as project size increases with the economy of scale coefficient generally ranging from 0 to -1. These preliminary findings motivated the development of the M* bidding strategy.

Using the above relationship, one begins to formulate a bidding policy by fitting the observed perceived markups of the low bidder as a function of estimated project cost for all past projects in a given market or class of work. (Obviously, the contractor with no information of past competitively bid projects need not consider this analytical procedure and must continue conceptual pricing practices until a data base is established). The perceived markup is found by the relationship:

$$\text{Perceived Markup} = \frac{\text{Low Bid} - \text{Our Cost Estimate}}{\text{Our Cost Estimate}} \qquad (A.2)$$

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All projects, won or lost, should be included in the data base. For projects won by the contractor, the perceived markup represents the actual markup applied to the cost estimate. For projects won by a competitor, the perceived markup is a perception of the competitor's pricing policy with respect to the contractor's estimated cost. Figure A.1 shows a plot of perceived markups versus estimated project costs and the fitted line, $M = A + CX^K$. The relationship between the two variables, M and X, is statistical and residuals (or errors) may be associated with each observation with respect to the fitted line. Residual is defined as the observed markup minus the predicted markup; thus,

$$\text{Residual} = (\text{Observed M}) - (A + CX^K) \qquad (A.3)$$

The residuals represent some unexplained variability in the observations and may be approximated and described by the R-S distribution if homoscedasticity of the residuals is obtained. Homoscedasticity exists if the mean of the residuals is zero and the variance around the fitted equation is constant over the entire range of the independent variable. Figure A.2 shows a residual plot where the residuals may be considered homoscedastic. The zero residual line in this plot represents the value of the markup found by the fitted equation, $M = A + CX^K$. It is often difficult to visually test for homoscedasticity since data sets are relatively small; however, one must look for trends in the residual plot to make the assumption that homoscedasticity does or does not exist. Figure A.3 shows a residual plot where homoscedasticity does not exist. The absence of homoscedasticity requires further refinement

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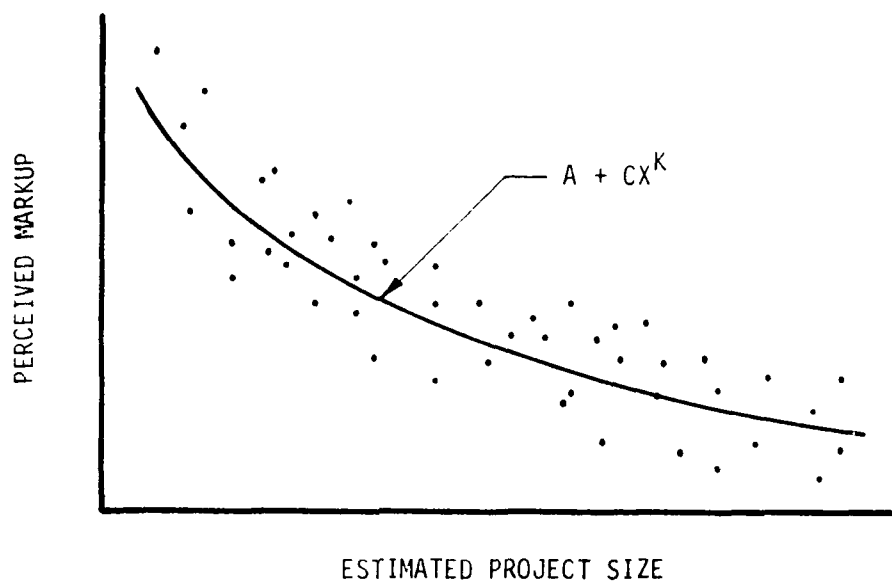
FIGURE A.1 -- PERCEIVED MARKUP VERSUS ESTIMATED
PROJECT SIZE
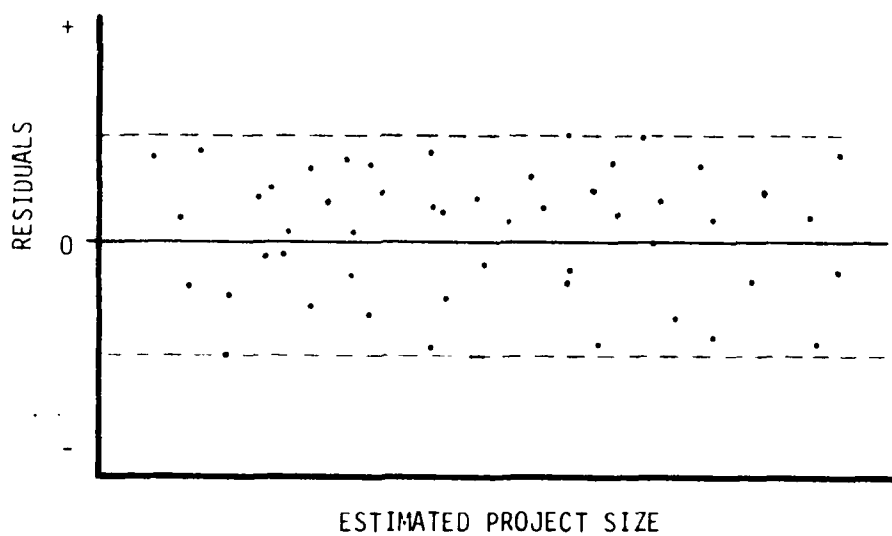
FIGURE A.2 -- HOMOSCEDASTIC RESIDUALS

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of data and/or additional analysis to remove some unexplained quantita

tive or qualitative factor.

Assuming homoscedasticity exists, the predicted equation is im-

proved by including a description of the residuals, R(p), approximatec

using the R-S distribution, and the equation becomes,

$$M = A + CX^K + R(p) \qquad\qquad (A.4)$$

The R-S distribution is a percentile distribution that characterizes a

random variable as a function of its cumulative probability. The dis-

tribution works well in pricing studies since markup (a random variabl

is a function of the probability of winning. To use the R-S distribu-

tion, one must first determine the first, second, third and fourth

sample moments of the residuals around the fitted line, $A + CX^K$, and

then standardize (make dimensionless) the third and fourth moments.

The third standardized moment is a measure of the symmetry (skewness)

and the fourth standardized moment is a measure of the peakedness

(kurtosis) of the residuals around the fitted line. The impact of

these calculations may be understood by examining the probability dis-

tribution function (pdf) of the residuals. Construction of the pdf ma;

be visualized by rotating the residual plot, such as the one shown in

Figure A.2, 90 degrees clockwise and mapping the residuals down to the

residual axis. One may visualize the construction of a histogram for

the residuals, shown in Figure A.4, such that each residual is mapped

into the appropriate interval. The dotted line in Figure A.4 repre-

sents the pdf of the residuals. This distribution appears to be

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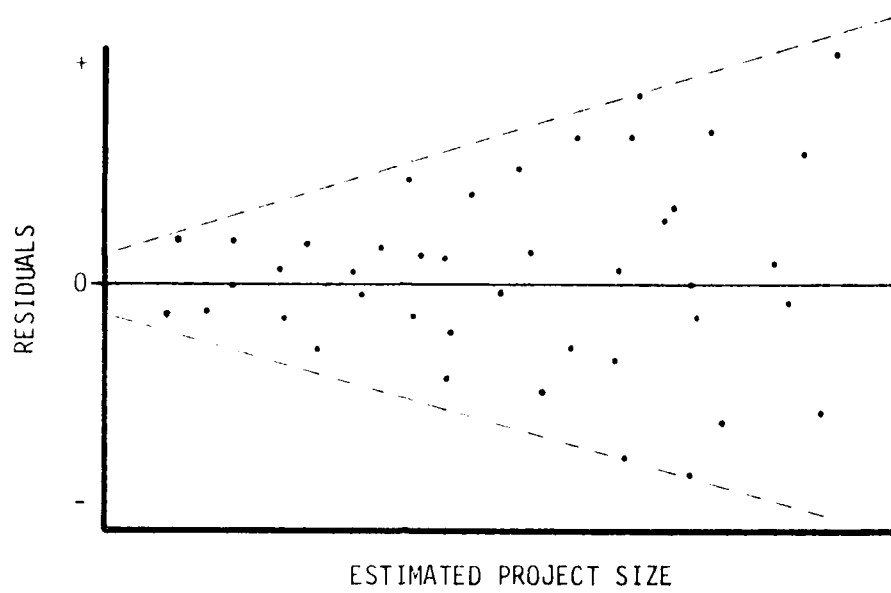
FIGURE A.3 -- NON-HOMOSCEDASTIC RESIDUALS
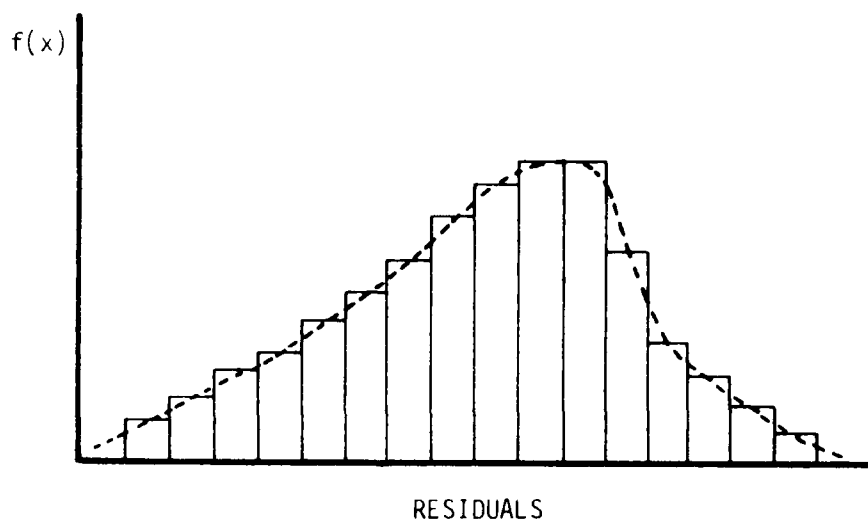
FIGURE A.4 -- HISTOGRAM OF RESIDUALS

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negatively skewed, thus, the third standardized moment will be some value less than zero (the skewness of a symmetrical distribution, such as the normal distribution, is zero). It is very difficult to visually estimate the peakedness of a distribution; however, this distribution appears to be more peaked (a higher value of kurtosis) than, for example, a normal distribution. It is emphasized that, while the pdf may be constructed with the R-S distribution by taking the inverse of the derivative of R(p), the cumulative distribution function is developed using the R-S distribution and the above calculated moments since markup is a function of the probability of winning. The cdf is constructed by iteratively determining the expected value of the residual (markup) for various probabilities of occurrence (from 0 to 1), as shown in Figure A.5. The probability, p, may be interpreted as the probability of not winning a contract at the corresponding markup; therefore, the probability of winning is (1 - p).

The above information may now be used to develop a bidding strategy aimed at maximizing expected net profits. Net profits for a project may be considered to equal the markup minus the costs of overhead and estimating, and expectancy theory states that the expected net profits for a project are:

$$E(\pi) = (A + CX^K + R(p))(1 - p) - C_0(1 - p) - C_{est} \quad (A.5)$$

where, $E(\pi)$ = Expected net profits,

$A + CX^K + R(p)$ = Markup,

$(1-p)$ = Probability of winning at the above markup

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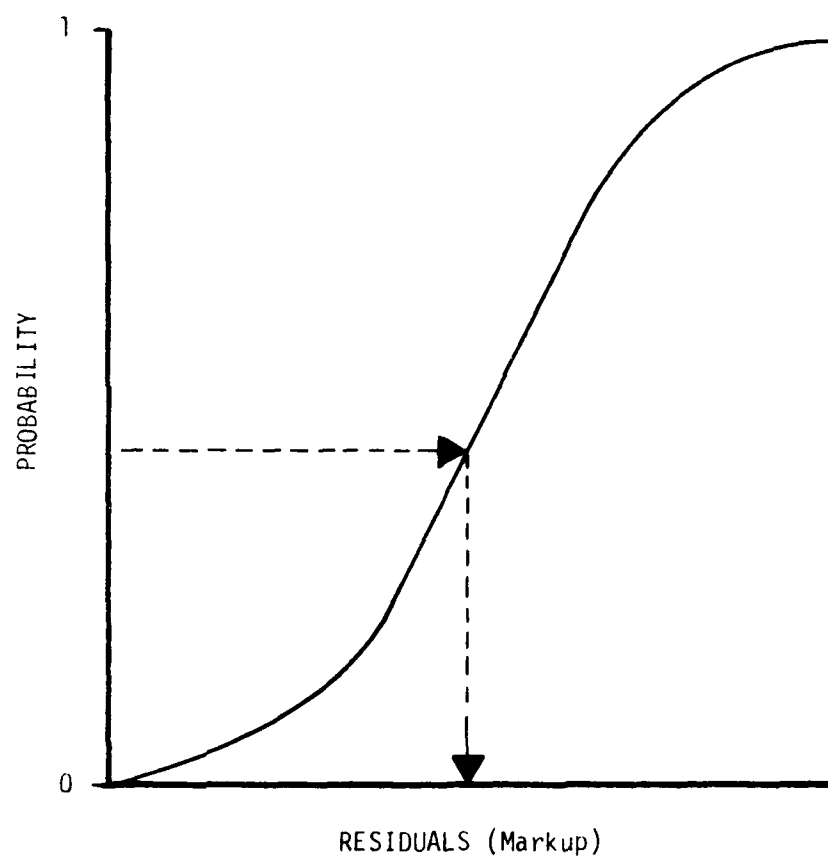
FIGURE A.5 -- CUMULATIVE DENSITY FUNCTION: MARKUP
        AS A FUNCTION OF P

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C_0 = Cost of overhead function, and

C_{est} = Cost of estimating function.

The expected net profits are maximum for the above relationship when $\frac{d}{dp} E(\pi) = 0$. Taking the derivative of the above equation and setting it equal to zero gives:

$$(1 - p) \frac{d}{dp} (R(p)) = A + CX^K + R(p) - C_0 \qquad (A.6)$$

The above equation may be solved by iterating p for any given project size, and the p that satisfies the relationship is termed p*. The p* associated with the residuals is also the p* for the total markup for any given project size since $A + CX^K$ is constant. The optimum markup to bid for a given project size is therefore:

$$M^* = A + CX^K + R(p^*) \qquad (A.7)$$

One may obtain a general bidding policy over a range of project sizes by calculating M* at, say, 20 levels of project size, and then fitting these M* observations as a function of project size by the equation:

$$M^* = A^* + C^* X^{K^*} \qquad (A.8)$$

This equation represents the M* bidding strategy.

A.2 The M** Bidding Strategy

The M** bidding strategy is a modification of the M* strategy that recognizes the constraints imposed on company operations by the backlog of work model. The contractor aware of these constraints, as discussed in Chapter 3, and currently tendering all competitively bid projects with the M* policy may possibly improve his bidding strategy by attempting to answer several questions. Does the backlog of work model affect the mean work completion rate? If so, at what levels of backlog should the optimum markup, M*, be modified to account for the constraints imposed by the model? How should M* be modified?

An understanding of the M** bidding strategy is best obtained by visualizing the backlog of work model and the constraints imposed on company operations. Figure A.6 shows a backlog of work curve for a given operation. The labels shown in Figure A.6 correspond to the labels used in the BACKLOG computer program. Point A is the lowest backlog and point B is the highest backlog at which the mean work completion rate, WMAX, is maximum (as determined by the work completion rate function). MAXPRO is the anticipated range of efficient operations and is equal to B minus A. APRIME is the low level of backlog and BPRIME is the high level of backlog at which M* is modified in some specified manner to account for the current backlog of work. These points are found by adding or subtracting MAXPRO x UPROA from point A and adding or subtracting MAXPRO x UPROB from point B. UPROA and UPROB are some specified proportions of MAXPRO. The M* bidding strategy is used at levels of backlog between APRIME and BPRIME, and for backlogs outside this interval, one must specify how M* will be

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modified.

Contractors typically increase the markup applied to a cost esti-
mate when their backlog of work is high to reflect a position that the
work is desired but only at a higher price. Conversely, contractors
typically decrease markup when their backlog of work is low to reflect
a relative desire or need to obtain work. One may note that for all
backlog of work curves, company operations are impacted at low levels
of backlog since only work that is currently available or will be avail-
able in the very near future can be completed. There is a great proba-
bility at low levels of backlog that secondary objectives, such as
keeping key personnel employed, are elevated to primary objectives and
that maximization of net profits (the assumed primary objective) is
temporarily removed from consideration. The backlog of work model may
not aid the contractor suffering from a lack of work unless these secon-
dary objectives can be quantified in some manner. At high levels of
backlog, there is a great probability that these secondary objectives
have been satisfied and that a contractor will strive to maximize net
profits. The backlog of work model and M** bidding strategy is, there-
fore, more adaptable to the study of the impact of the backlog of work
at high levels of backlog. Figure A.6 shows that beyond the backlog at
point B, operations become inefficient with respect to the mean work
completion rate. For example, at the backlog labelled U1, the work
completion rate drops from WMAX to WU1. This drop may be perceived as
an increase in costs if it is assumed that the modus operandi does not
change. One may hypothesize that personnel and equipment simply have

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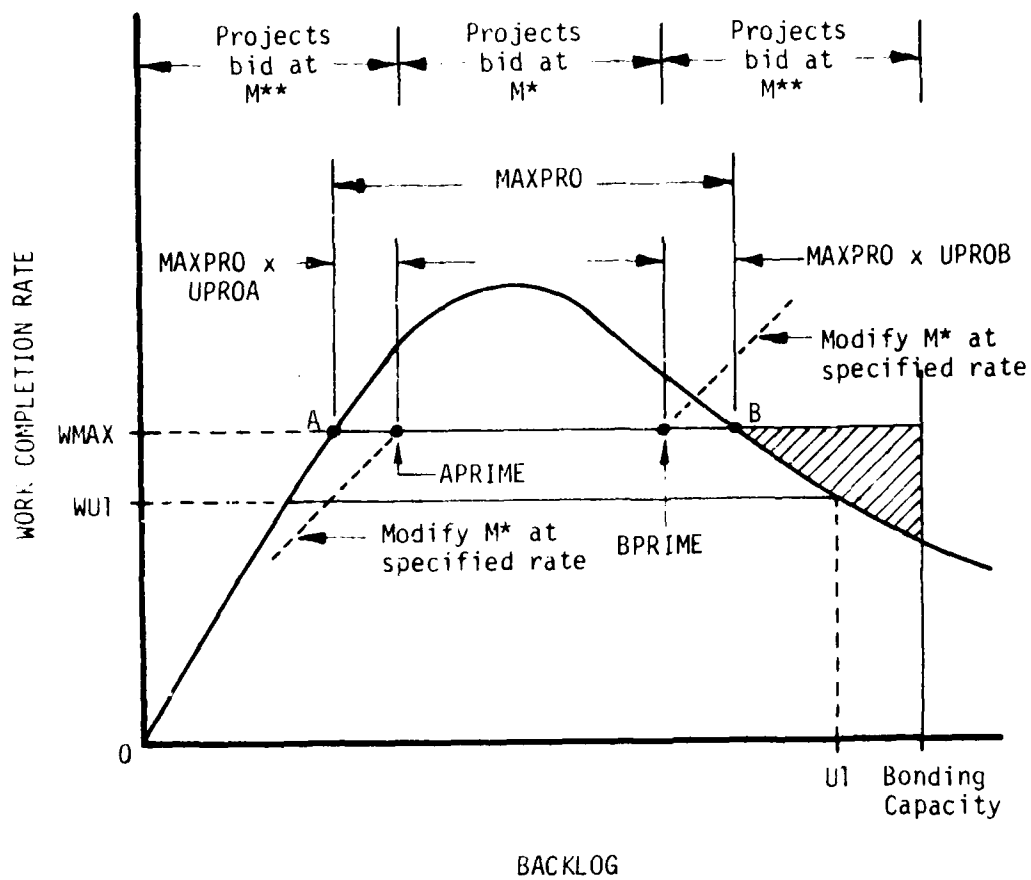
FIGURE A.6 -- MODIFYING M* TO ACCOUNT FOR THE
BACKLOG OF WORK

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too much work to accomplish and are spread so thinnly that optimum crew design and equipment utilization cannot be achieved. If it is further assumed that material costs and equipment owning costs do not increase, only some proportion of the difference between WMAX and WUl is lost due to higher labor costs and equipment operating costs. A contractor does not normally desire such a situation unless the potential exists for financially offsetting these higher costs (i.e., the project can be bid and won at a higher markup).

It should be clear that the M^{**} bidding policy is determined by an iterative procedure. One must determine where and to what degree M^* should be altered to maximize net profits within the constraints of the backlog of work curve for the given operation and given market conditions. Market conditions may be very important if, for example, the bid-get ratio is very high. The probability of winning may be very sensitive to slight changes in the markup, and the policy of increasing markup at high levels of backlog may prove to be self-defeating. On the other hand, there may be cases where a contractor can more than offset cost overruns and potential increases in estimating costs by increasing the markup applied to the cost estimate.

APPENDIX B

USER DOCUMENTATION

This Appendix presents information required to use and understand the BACKLOG program. Figure B.1 shows a sample BACKLOG control deck to include sample user specified information. This control deck may be used only if the BACKLOG program is in object mode on disk storage. Should this mode not be available, the card deck of the program and the appropriate job control language must be used. All disk storage required by the program is temporary and deleted at the end of each run; therefore, job control language changes must be made in the control deck to save output for further computer analysis or other uses.

User inputs are outlined in Table B.1. All inputs are the results of previous studies and characterize a given company operation and its place in the market. Representative data for the various distributions may be found in the works of Larew (14) and graduate student theses (8, 10, 17).

Table B.2 describes the printing and executing options available to the user. PRNOP1 (print option 1) should equal 0 or 1 unless the simulation results are unreasonable or changes to the BACKLOG program are being made. Unreasonable results may be the result of improperly developed bidding policies for the contractor and the competitor (the low bidder), decimal or punching errors or any number of user input mistakes.

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Only after all inputs have been checked should the user specify that PRNOP1 is equal to 2 or 3. These options require a great deal of printing time and, generally, a large output; therefore, only one sample should be run (NSAMPL = 1) for no more than 12 months (NMONTH ≤ 12). These last two printing options are also valuable in gaining an understanding of the program logic. A complete list of program variables is presented in Table B.3.

To a large degree, the BACKLOG program is a bookkeeping exercise. The actual simulation of a competitive market and the various costs incurred by the contractor is fairly short and the bulk of the program is dedicated to keeping track of costs, projects won, projects in progress, profits from projects completed, etc. Bookkeeping is performed in the program primarily by three arrays: PROF1, PROF2 and GDIST. Table B.4 presents a schematic array PROF1. This 200 by 9 matrix is used to keep track of all projects won by the contractor bidding at M*. Array PROF2 is similar to array PROF1 and is used when the contractor is bidding at M**. The array GDIST is used to store the distribution parameters for the monthly simulation results, and a schematic of this array is shown in Table B.5

Additional documentation for the BACKLOG program is presented in Appendix C, the program listing, and Appendix D, the program flowchart.

```
// JOB CARD
// TIME=(2,),REGION=192K
/*JOBPARM LINES=10000,DISKIO=5000,SERVICE=EXPRESS
// EXEC FTG1G
//GO.FT01F001 DD DSN=      .MOMENTS.DATA,DISP=SHR
//GO.FT08F001 DD DSN=      .DIST08.DATA,
// UNIT=USERDA,SPACE=(TRK,(10,5),RLSE),
// DCB=(RECFM=FB,LRECL=20,BLKSIZE=1200),DISP=(NEW,DELETE)
//GO.FT09F001 DD DSN=      .DIST09.DATA,
// UNIT=USERDA,SPACE=(TRK,(10,5),RLSE),
// DCB=(RECFM=FB,LRECL=20,BLKSIZE=1200),DISP=(NEW,DELETE)
//GO.FT10F001 DD DSN=      .DIST10.DATA,
// UNIT=USERDA,SPACE=(TRK,(10,5),RLSE),
// DCB=(RECFM=FB,LRECL=40,BLKSIZE=2400),DISP=(NEW,DELETE)
//GO.FT11F001 DD DSN=      .DIST11.DATA,
// UNIT=USERDA,SPACE=(TRK,(10,5),RLSE),
// DCB=(RECFM=FB,LRECL=40,BLKSIZE=2400),DISP=(NEW,DELETE)
//GO.FT12F001 DD DSN=      .DIST12.DATA,
// UNIT=USERDA,SPACE=(TRK,(10,5),RLSE),
// DCB=(RECFM=FB,LRECL=60,BLKSIZE=3600),DISP=(NEW,DELETE)
//GO.FT13F001 DD DSN=      .DIST13.DATA,
// UNIT=USERDA,SPACE=(TRK,(10,5),RLSE),
// DCB=(RECFM=FB,LRECL=60,BLKSIZE=3600),DISP=(NEW,DELETE)
//GO.FT14F001 DD DSN=      .DIST14.DATA,
// UNIT=USERDA,SPACE=(TRK,(10,5),RLSE),
// DCB=(RECFM=FB,LRECL=50,BLKSIZE=3000),DISP=(NEW,DELETE)
//SYSIN DD DSN=      .BACKLOG.OBJ,DISP=SHR
//GO.SYSIN DD *
RHYE        26 DEC 79
        1          12         61
   5.0E00     4.0E02     0.5E00
ARRIVAL RATE
    .35E02    .8333E01    0.0E00     1.4E00
JOB SIZE
   0.10E03   .1681E04    -.45E00     .32E01
SUBJECT MARKUP                    2.2875E-010.4246E+00-.3167E+00

COST OF ESTIMATING                0.0000E+000.1500E+000.3750E+00

COST OF OVERHEAD                  0.0000E+000.3000E+000.7406E+00

COMPETITOR MARKUP             0.9944E-010.6601E+00-.3612E+00
       0.0E00 .5415E-010.2000E+000.2600E+01
         0           0           1           0
   22092503              89771209?           1417473372            553645566
  755310619
   10.00000             5.00000            -.00001
 0.400E-02  0.100E+01  0.600E+02  0.100E+02
 0.400E-02  0.100E+01  0.600E+02  0.150E+02
 0.400E-02  0.100E+01  0.600E+02  0.200E+02
 0.400E-02  0.100E+01  0.600E+02  0.250E+02
 0.400E-02  0.100E+01  0.600E+02  0.500E+02
 0.400E-02  0.100E+01  0.600E+02  0.100E+03
 0.400E-02  0.100E+01  0.600E+02  0.200E+03
 0.400E-02  0.100E+01  0.600E+02  0.300E+03
 0.400E-02  0.100E+01  0.600E+02  0.400E+03
 0.400E-02  0.100E+01  0.650E+02  0.100E+02
 0.400E-02  0.100E+01  0.650E+02  0.150E+02
 0.400E-02  0.100E+01  0.650E+02  0.200E+02
/*
//
```

FIGURE B.1 -- BACKLOG CONTROL DECK

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TABLE B.1 -- INPUTS FOR THE BACKLOG PROGRAM

CARD	VARIABLE	TYPE	COLUMNS	DESCRIPTION	COMMENTS
1	TITLE	15A4	1-60		For identification purposes only
2	NEXPMT NSAMPL NMONTH	I3 I4 I3	8-10 17-20 28-30	See variable listing	Number of samples Number of months
3	MINJS MAXJS LABEQP	E10.4 E10.4 E10.4	1-10 11-20 21-30	See variable listing	
4	NAME(1,K) DIST(1,1) DIST(1,2) DIST(1,3)	5A4 E10.4 E10.4 E10.4	1-20 31-40 41-50 51-60	 A C K	Cards 4 and 5 contain all parameters required to describe the distribution of the arrival rate of bid opportunities.
5	DIST(1,4) DIST(1,5) DIST(1,6) DIST(1,7)	E10.4 E10.4 E10.4 E10.4	1-10 11-20 21-30 31-40	M1 M2 ALPHA 3 ALPHA 4	
6	NAME(2,K) DIST(2,1) DIST(2,2) DIST(2.3)	5A4 E10.4 E10.4 E10.4	1-20 31-40 41-50 51-60	 A C K	Cards 6 and 7 contain all parameters required to describe the distribution of project size for the bid opportunities.
7	DIST(2,4) DIST(2,5) DIST(2,6) DIST(2,7)	E10.4 E10.4 E10.4 E10.4	1-10 11-20 21-30 31-40	M1 M2 ALPHA 3 ALPHA 4	
8	NAME(3,K) DIST(3,1) DIST(3,2) DIST(3,3)	5A4 E10.4 E10.4 E10.4	1-20 31-40 41-50 51-60	 A* C* K*	Cards 8 and 9 contain all parameters required to describe the subject contractor's M* bidding policy. Card 9 should be left blank.
9	DIST(3,4) DIST(3,5) DIST(3,6) DIST(3.7)	E10.4 E10.4 E10.4 E10.4	1-10 11-20 21-30 31-40	M1 M2 ALPHA 3 ALPHA 4	

CARD	VARIABLE	TYPE	COLUMNS	DESCRIPTION	COMMENTS
10	NAME(4,K)	5A4	1-20		Cards 10 and 11 contain all parameters required to describe the cost of estimating function.
	DIST(4,1)	E10.4	31-40	A	
	DIST(4,2)	E10.4	41-50	C	
	DIST(4,3)	E10.4	51-60	K	
11	DIST(4,4)	E10.4	1-10	M1	
	DIST(4,5)	E10.4	11-20	M2	
	DIST(4,6)	E10.4	21-30	ALPHA 3	
	DIST(4,7)	E10.4	31-40	ALPHA 4	
12	NAME(5,K)	5A4	1-20		Cards 12 and 13 contain all parameters required to describe the cost of overhead function.
	DIST(5,1)	E10.4	31-40	A	
	DIST(5,2)	E10.4	41-50	C	
	DIST(5,3)	E10.4	51-60	K	
13	DIST(5,4)	E10.4	1-10	M1	
	DIST(5,5)	E10.4	11-20	M2	
	DIST(5,6)	E10.4	21-30	ALPHA 3	
	DIST(5,7)	E10.4	31-40	ALPHA 4	
14	NAME(6,K)	5A4	1-20		Cards 14 and 15 contain all parameters required to describe the low bidder's markup policy.
	DIST(6,1)	E10.4	31-40	A	
	DIST(6,2)	E10.4	41-50	C	
	DIST(6.3)	E10.4	51-60	K	
15	DIST(6,4)	E10.4	1-10	M1	
	DIST(6,5)	E10.4	11-20	M2	
	DIST(6,6)	E10.4	21-30	ALPHA 3	
	DIST(6,7)	E10.4	31-40	ALPHA 4	
16	PRNOP1	I1	10	See variable listing	
	PROOP2	I1	20		
	EXOPT1	I1	30		
	EXOPT2	I1	40		
17	ISEED1	I10	1-10	See variable listing	Initial seed values for the input distributions.
	ISEED2	I10	21-30		
	ISEED4	I10	41-50		
	ISEED5	I10	61-70		
18	ISEED6	I10	1-10		

CARD	VARIABLE	TYPE	COLUMNS	DESCRIPTION	COMMENTS
19	RATBC RATMMA RATMMB	F10.6 F10.6 F10.6	1-10 21-30 41-50	See variable listing	
20-N	KB CB WMAX OPTJS	E10.4 E10.4 E10.4 E10.4	1-10 11-20 21-30 31-40	See variable listing	Cards 20 through N contain the information required to construct the back-log of work curve for the sample. If 10 samples are to be run at the same time then cards 20 through 29 would contain the informa-tion for each sample.

TABLE B.2 -- PRINTING AND EXECUTING OPTIONS

OPTION	VALUE	DESCRIPTION
PRNOP1	0	Print short summary only. This is the recommended option unless the distributions of generated data are desired.
	1	Print long summary, to include all information above and data stored in array GDIST.
	2	Print information for each project as completed and the short summary.
	3	Print information for each step of the program where data is generated or tested. Do not use this option if the number of samples is greater than 1 and the number of months is greater than 12.
PRNOP2	1	Punch information on cards. This option may only be used when PRNOP1 equals 0 or 1.
EXOPT1	1	Project size will be constant and equal to OPTJS input. If EXOPT1 is not equal to 1, the project size will vary with the distribution of project size input.
EXOPT2	0 1 2 3 4 5 GT6	UPROA=0. and UPROB=0. UPROA=.5 and UPROB=.5 UPROA=.2 and UPROB=.1 UPROA=.2 and UPROB=.2 UPROA=.3 and UPROB=.1 UPROA=.3 and UPROB=.3 UPROA=.5 and UPROB=.1 This option must be used and should equal 0 if unfamiliar with the program. The program may be easily changed if none of the above values are adequate.

TABLE B.3 -- BACKLOG VARIABLE LISTING

Variable	Description
A	The low backlog of work for a given curve where the mean work completion rate is maximum.
ACTCT1	Actual Cost of a project with the contractor bidding at M*.
ACTCT2	Actual cost of a project with the contractor bidding at M**.
AMD1	Total market dollars with the contractor bidding at M*.
AMD2	Total market dollars with the contractor bidding at M**.
APRIME	The low backlog of work for a given curve where M* is modified.
B	The high backlog of work for a given curve where the mean work completion rate is maximum.
BONDCP	Bonding capacity.
BPRIME	The high backlog of work for a given curve where M* is modified..
C	Interval used to test if the specified skewness and kurtosis match the values in MOMENTS.DATA. If so, lambda parameters are assigned to the array LAM.
CACCT1	Cumulative actual costs for the contractor bidding at M*.
CACCT2	Cumulative actual costs for the contractor bidding at M**.
CAC1	Cumulative costs exceeding estimated costs for the contractor bidding at M*.
CAC2	Cumulative costs exceeding estimated costs for the contractor bidding at M**.
CAWC	Variable used to test if a project is completed at the end of the month.
CB	The perceived opportunity for individual achievement parameter specified for each sample.

TABLE B.3 -- BACKLOG VARIABLE LISTING (Continued)

Variable	Description
CBID1	Cumulative bids for projects completed with the contractor bidding at M*.
CBID2	Cumulative bids for projects completed with the contractor bidding at M**.
CBIDM	Counter for the number of projects bid at M*.
CBIDMM	Counter for the number of projects bid at M**.
CCBID1	Cumulative bids for projects won by the competitor with the contractor bidding at M*.
CCBID2	Cumulative bids for projects won by the competitor with the contractor bidding at M**.
CCJBS1	Cumulative estimated costs for projects won by the competitor with the contractor bidding at M*.
CCJBS2	Cumulative estimated costs for projects won by the competitor with the contractor bidding at M**.
CCWONM	Counter for the number of projects won by the competitor with the contractor bidding at M*.
CCWNMM	Counter for the number of projects won by the competitor with the contractor bidding at M**.
CCOMM	Counter for the number of projects completed with the contractor bidding at M*.
CCOMMM	Counter for the number of projects completed with the contractor bidding at M**.
CEC1	Cumulative estimating costs for projects completed with the contractor bidding at M*.
CEC2	Cumulative estimating costs for projects completed with the contractor bidding at M**.
CGP1	Cumulative gross profits for projects completed with the contractor bidding at M*.
CGP2	Cumulative gross profits for projects completed with the contractor bidding at M**.

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TABLE B.3 -- BACKLOG VARIABLE LISTING (Continued)

Variable	Description
CHCKU	Middle of the interval, MAXPRO, used to determine when start-up ends and the sample begins.
CJBSIZ	Cumulative project size of all bid opportunities.
CJS1	Cumulative estimated costs for all projects completed with the contractor bidding at M*.
CJS2	Cumulative estimated costs for all projects completed with the contractor bidding at M**.
CIER	Counter used to determine if the program should terminate when lambda parameters for all distributions specified are not found.
CMRKUP	Competitor's markup for a project.
CNJOBS	Counter for the total number of bid opportunities.
CNP1	Cumulative net profits for projects completed with the contractor bidding at M*.
CNP2	Cumulative net profits for projects completed with the contractor bidding at M**.
COHC1	Cumulative overhead costs for projects completed with the contractor bidding at M*.
COHC2	Cumulative overhead costs for projects completed with the contractor bidding at M**.
COMBID	Competitor's bid for a project.
CPGP1	Cumulative perceived gross profits of the competitor with the contractor bidding at M*.
CPGP2	Cumulative perceived gross profits of the competitor with the contractor bidding at M**.
CTEC1	Cumulative estimating costs for all projects bid by the contractor at M*.
CTEC2	Cumulative estimating costs for all projects bid by the contractor at M**.

TABLE B.3 -- BACKLOG VARIABLE LISTING (Continued)

Variable	Description
CUW	Counter for the number of months a sample was run. Equals NMONTH minus 1.
CU1	Cumulative backlog of work at the end of each month with the contractor bidding at M*.
CU2	Cumulative backlog of work at the end of each month with the contractor bidding at M**.
CWLR1	Cumulative costs exceeding estimated costs for all projects completed during the month with the contractor bidding at M*.
CWLR2	Cumulative costs exceeding estimated costs for all projects completed during the month with the contractor bidding at M**.
CWONM	Counter for the number of projects won by the contractor bidding at M*.
CWONMM	Counter for the number of projects won by the contractor bidding at M**.
CWR1	Cumulative amount of the work completion rate that is required for all projects completed during the month with the contractor bidding at M*.
CWR2	Cumulative amount of the work completion rate that is required for all projects completed during the month with the contractor bidding at M**.
CW1	Cumulative work completion rate each month with the contractor bidding at M*.
CW2	Cumulative work completion rate each month with the contractor bidding at M**.
DIST	Array to store parameters input for all distributions.
ESTCST	Cost of estimating for a project.
GDIST	Array to store all moments and the skewness and kurtosis of generated data.
GPP1	Perceived gross profits in the market with the contractor bidding at M*.

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TABLE B.3 -- BACKLOG VARIABLE LISTING (Continued)

Variable	Description
GPP2	Perceived potential gross profits in the market with the contractor bidding at M**.
IBOND	Integer equivalent of the bonding capacity.
INCR	Increment used to determine points A and B on the backlog of work curve.
INJMON	Counter for the number of projects required during startup.
ISEED1	Initial seed value for the distribution of the arrival rate of bid opportunities.
ISEED2	Initial seed value for the distribution of project size.
ISEED4	Initial seed value for the distribution for the cost of estimating.
ISEED5	Initial seed value for the distribution of the cost of overhead.
ISEED6	Initial seed value for the distribution of the competitor's markup.
JOBSIZ	Estimated cost of a project.
KB	The decision making time interval parameter specified for each sample.
LAM	Array to store the lambda parameters for input distributions.
LABEQP	Proportion of total estimated cost for labor and equipment operating costs.
MAXJS	The maximum project size normally bid by the contractor.
MAXPRO	The maximum range of efficient operations for a given backlog of work curve.
MINJS	The minimum project size normally bid by the contractor.
MODMUP	The modified markup for the M** bidding policy.
MSBBID	The bid for the M** bidding policy.

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TABLE B.3 -- BACKLOG VARIABLE LISTING (Continued)

Variable	Description
NAME	Array to store the names of input distributions.
NE	Counter for the number of experiments.
NEXPMT	Number of experiments for the entire run.
NBM	Variable used in testing if an opportunity may be bid by the contractor at M*.
NBMM	Variable used in testing if an opportunity may be bid by the contractor at M**.
NJ	Counter for the number of bid opportunities in a month.
NJOBS	The number of bid opportunities generated for a given month.
NM	Counter for the number of months.
NMONTH	The number of months to run each sample.
NP	Number of projects remaining in either array PROF1 or PROF2.
NS	Counter for the number of samples.
NSAMPL	The number of samples per experiment.
OHCOST	Cost of overhead for a project.
OPTJS	Value of project size that is constant for a sample.
PN	Counter for arrays PROF1 and PROF2.
PP1	Perceived gross profits for a project awarded in the market with the contractor bidding at M*.
PP2	Perceived gross profits for a project awarded in the market with the contractor bidding at M**.
PROF1	Array used to store all projects won by the contractor bidding at M*. Projects are loaded in this array when won and deleted when complete.
PROF2	Array used to store all projects won by the contractor bidding at M**. Projects are loaded in this array when won and delected when completed.

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TABLE B.3 -- BACKLOG VARIABLE LISTING (Continued)

Variable	Description
PROJU1	Projected backlog of work if a project is won at M*.
PROJU2	Projected backlog of work if a project is won at M**.
PRONUM	Project number assigned to all bid opportunities.
P1	Probability associated with the random variability of the distribution of the arrival rate of bid opportunities.
P2	Probability associated with the random variability of the distribution of project size.
P4	Probability associated with the random variability of the cost of estimating for a project.
P5	Probability associated with the random variability of the cost of overhead for a project.
P6	Probability associated with the random variability of the distribution of the competitor's markup.
RATBC	The rate that bonding capacity is set by working capital.
RATMMA	The rate that M* is modified at backlogs less than APRIME.
RATMMB	The rate that M* is modified at backlogs greater than BPRIME. If negative, a project is not bid that will project backlog beyond BPRIME.
SMRKUP	The markup for the M* bidding policy.
SUBBID	The bid for the M* bidding policy.
TAMD1	Total awarded market dollars with the contractor bidding at M*.
TAMD2	Total awarded market dollars with the contractor bidding at M**.
TESTAB	Variable used to test if points A and B on the backlog of work curve are very close. In this case, the maximum work completion rate is established at the peak of the backlog curve.

TABLE B.3 -- BACKLOG VARIABLE LISTING (Continued)

Variable	Description
TESTPN	Variable used to check if a project was awarded to the competitor with the contractor bidding at M* to eliminate double printing if won by the competitor with the contractor bidding at M**.
TESTW1	Variable used to determine where M* will be modified.
TESTW2	Variable used to determine where M* will be modified.
TINC	Increment used to test if points A and B are close on the backlog of work curve.
U	Backlog of work used to determine where M* will be modified.
TITLE	Specified identification label for a computer run.
UPROA	Specified proportion of MAXPRO used to locate APRIME.
UPROB	Specified proportion of MAXPRO used to locate BPRIME.
U1	Backlog of work at the end of the month with the contractor bidding at M*.
U2	Backlog of work at the end of the month with the contractor bidding at M**.
W	Work completion rate used to determine where M* will be modified.
WLP1	Proportion of the monthly work lost rate associated with a project to be competed during the month with the contractor bidding at M*.
WLP2	Proportion of the monthly work lost rate associated with a project to be completed during the month with the contractor bidding at M**.
WLRM1	Proportion of the monthly work lost rate remaining after any projects have been completed with the contractor bidding at M*.
WLRM2	Proportion of the monthly work lost rate remaining after any projects have been completed with the contractor bidding at M**.

TABLE B.3 -- BACKLOG VARIABLE LISTING (Continued)

Variable	Description
WLR1	Proportion of the monthly work lost rate associated with a project that is completed during the month with the contractor bidding at M*.
WLR2	Proportion of the monthly work lost rate associated with a project that is completed during the month with the contractor bidding at M**.
WL1	Equivalent to the mean work completion rate, WMAX, minus the actual work completion rate during the month, W1, times the proportion of the estimated cost associated with labor and equipment operating costs. Referred to as the work lost rate for the contractor bidding at M*.
WL2	Same as above except the contractor is bidding at M**.
WMAX	The mean work completion rate specified by the user.
WNLP1	Proportion of the monthly work lost rate that is distributed to all projects not completed during the month with the contractor bidding at M*.
WNLP2	Same as above except the contractor is bidding at M**.
WNP1	Proportion of the monthly work completion rate that is distributed to all projects not completed during the month with the contractor bidding at M*.
WNP2	Same as above except the contractor is bidding at M**.
WP1	Proportion of the monthly work completion rate that is temporarily distributed to all projects backlogged by the contractor bidding at M*. Projects not requiring the entire amount of this proportion to be completed are closed out using only the proportion of the work completion rate required.
WP2	Same as the above except the contractor is bidding at M**.
WRM1	Proportion of the work completion rate that remains after all projects are completed during the month with the contractor bidding at M*.
WRM2	Same as the above except the contractor is bidding at M**.

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TABLE B.3 -- BACKLOG VARIABLE LISTING (Continued)

Variable	Description
WR1	Proportion of the work completion rate required to complete a project with the contractor bidding at M*.
WR2	Same as the above except the contractor is bidding at M**.
W1	Monthly work completion rate with the contractor bidding at M*.
W2	Monthly work completion rate with the contractor bidding at M**.

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TABLE B.4 -- SCHEMATIC OF ARRAY PROFT

Project Number	Estimated Cost	Bid at M*	Actual Work Completed	Actual Cost	Gross Profit	Cost of Estimating	Cost of Overhead	Net Profit
(1,1)	(1,2)	(1,3)	(1,4)	(1,5)	(1,6)	(1,7)	(1,8)	(1,9)
(2,1)	(2,2)							.
(3,1)	(3,2)	(3,3)						.
. .			.					.
. .				.				.
. .					.			.
. .						.		.
(200,1)	.	.	.	.	.	.	(200,8)	(200,9)

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TABLE B.5 -- SCHEMATIC OF ARRAY GDIST

DISTRIBUTION	M1	M2	M3	M4	ALPHA 3	ALPHA 4
Arrival rate of bids	(1,1)	(1,2)	(1,3)	(1,4)	(1,5)	(1,6)
Estimated cost	(2,1)					
Estimated cost at M*	(3,1)	.				
Bid at M*	.					
Actual cost at M*	.					
Gross profits at M*	.					
Net profits at M*	.		.			
Estimated cost at M**	.					
Bid at M**	.					
Actual cost at M**	.					
Gross profits at M**	.					
Net profits at M**	.			.		
Monthly backlog M*	.					
Work completion rate	.					
Monthly backlog M**	.					
Work completion rate	.					
Competitor cost M*	.					
Competitor bid M*	.				.	
Competitor profits M*	.					
Competitor cost M**	.					
Competitor bid M**	.					
Competitor profits	(22,1)	(22,2)	(22,3)	(22,4)	(22,5)	(22,6)

APPENDIX C

BACKLOG LISTING

This appendix contains the FORTRAN listing of the BACKLOG comput-
er program. Comment cards are included that describe the function of
set of statements or operations. These comments correspond closely to
the box titles in the program flowchart that is presented in Appendix
D.

```
C                                                                         00000010
C                                                                         00000020
C                                                                         00000030
C     DECLARATION OF VARIABLES.                                           00000040
C                                                                         00000050
C                                                                         00000060
C                                                                         00000070
      INTEGER TITLE, NSAMPL, NMONTH, NAME, PRNOP1, NS, ISEED1, NM, NJ,    00000080
     $ NJOBS,ISEED1,ISEED2,ISEED4,ISEED5,ISEED6,PRNOP1,PRNOP2,PN,         00000090
     $ NF,CIER,NE,NEXPMT,EXOPT1,CNJOBS,CWONM,CWONMM,NIE,CBIDM,CBIDMM,     00000100
     $ NBM,NBMM,CCOMM,CCOMMM,CUW,CCWONM,CCWNMM,EXOPT2,INCR,IBOND,PRNOP3,  00000110
     $ U                                                                  00000120
      REAL KB, CB, DIST, LAM, P1, P2, P3, P4, WMAX, MINJS,                00000130
     $ MAXJS, BONDCP, JOBSIZ, W1, W2, U1, U2, PROJU1, PROJU2, SMRKUP,     00000140
     $ SUBBID, MODMUP, MSBBID, CMRKUP, COMBID, PROF1, PROF2, WL1, WL2,    00000150
     $ WP1, WP2, WLP1, WLP2, WR1, WR2, WLR1, WLR2, CAWC, CWR1, CWR2,      00000160
     $ CWLR1, CWLR2, CJS1, CJS2, CBID1, CBID2, CAWC1, CAWC2, CAC1, CAC2,  00000170
     $ CU1, CU2, WRM1, WRM2, WLRM1, WLRM2, WNP1, WNP2, WNLP1, WNLP2,      00000180
     $ ESTCST,OHCOST,LABEQP,OPTJS,CEC1,CEC2,COHC1,COHC2,CTEC1,CTEC2,      00000190
     $ CGF1,CGF2,CNP1,CNP2,PRONUM,TESTPN,ACTCT1,ACTCT2,CJBSIZ,CACCT1,     00000200
     $ CACCT2,GDIST,XMX,DATA,CW1,CW2,AMD1,AMD2,FP1,FP2,TAMD1,TAMD2,       00000210
     $ GFF1,GFF2,CCJBS1,CCJBS2,CCBID1,CCBID2,CFGP1,CFGP2,TESTW1,TESTW2,   00000220
     $ A,B,MAXPRO,APRIME,BPRIME,UPROA,UPROB,TINCR,TESTAB                  00000230
      COMMON /LAMBDA/ LAM(6,4)                                            00000240
      DIMENSION NAME(6,5), DIST(6,7), TITLE(15), PROF1(200,9),            00000250
     $ PROF2(200,9), GDIST(22,6), XMX(22), DATA(22)                       00000260
C                                                                         00000270
C                                                                         00000280
C                                                                         00000290
C     USER SPECIFIED INFORMATION.                                         00000300
C                                                                         00000310
C                                                                         00000320
C                                                                         00000330
      READ(5,10) (TITLE(I), I=1,15)                                       00000340
   10 FORMAT(15A4)                                                        00000350
C                                                                         00000360
      READ(5,20) NEXPMT,NSAMPL,NMONTH                                     00000370
   20 FORMAT(7X,I3,6X,I4,7X,I3)                                           00000380
C                                                                         00000390
      READ(5,40) MINJS,MAXJS,LABEQP                                       00000400
   40 FORMAT(3E10.4)                                                      00000410
C                                                                         00000420
      DO 1000 I=1,6                                                       00000430
      READ(5,50) (NAME(I,K), K=1,5),(DIST(I,J), J=1,7)                    00000440
   50 FORMAT(5A4,10X,3E10.4,/,4E10.4)                                     00000450
 1000 CONTINUE                                                            00000460
C                                                                         00000470
      READ(5,60) PRNOP1,PRNOP2,EXOPT1,EXOPT2                              00000480
   60 FORMAT(9X,I1,9X,I1,9X,I1,9X,I1)                                     00000490
C                                                                         00000500
      READ(5,61) ISEED1,ISEED2,ISEED4,ISEED5,ISEED6                      00000510
   61 FORMAT(I10,10X,I10,10X,I10,10X,I10,/,I10)                           00000520
C                                                                         00000530
      READ(5,62) RATBC,RATMMA,RATMMB                                      00000540
   62 FORMAT(F10.6,10X,F10.6,10X,F10.6)                                   00000550
C                                                                         00000560
```

```
C                                                                        00000570
C                                                                        00000580
C    PRINT USER SPECIFIED INFORMATION.                                   00000590
C                                                                        00000600
C                                                                        00000610
C                                                                        00000620
      WRITE(6,70)                                                        00000630
   70 FORMAT('1',//,42X,48('*'),//,42X,'*',46X,'*',//,42X,'*',5X,        00000640
     $ 'SUMMARY OF USER SPECIFIED PARAMETERS', 5X,'*',//,42X,'*',46X,    00000650
     $ '*',//,42X,48('*'),///)                                           00000660
C                                                                        00000670
      WRITE(6,80) (TITLE(I),I=1,15),NEXPMT,NSAMPL,NMONTH                 00000680
   80 FORMAT(16X,'TITLE:',3X,15A4,//,16X,'EXPERIMENT SIZE PARAMETERS:',  00000690
     $//,18X,'NUMBER OF EXPERIMENTS:',2X,I3,/,18X,'NUMBER OF SAMPLES:',  00000700
     $1X,I4,/,18X,'MONTHS PER SAMPLE:',2X,I3,//)                         00000710
C                                                                        00000720
      WRITE(6,90)                                                        00000730
   90 FORMAT(16X,'MARKET PARAMETERS:',/)                                 00000740
C                                                                        00000750
      WRITE(6,100)                                                       00000760
  100 FORMAT(20X,'DISTRIBUTION',10X,'A',10X,'C',10X,'K',9X,'M1',9X,      00000770
     $'M2',7X,'ALPHA3',5X,'ALPHA4',/)                                    00000780
C                                                                        00000790
      DO 1001 I=1,2                                                      00000800
      WRITE(6,110) (NAME(I,K), K=1,5),(DIST(I,J), J=1,7)                 00000810
  110 FORMAT(18X,5A4,7(1X,E10.4))                                        00000820
 1001 CONTINUE                                                           00000830
C                                                                        00000840
      WRITE(6,120) MINJS,MAXJS                                           00000850
  120 FORMAT(//,16X,'SUBJECT COMPANY PARAMETERS:',//,18X,'MINIMUM JOB SI 00000860
     $ZE NORMALLY BID:',11X,E10.4,//,18X,'MAXIMUM JOB SIZE NORMALLY BID:'00000870
     $,11X,E10.4,/,18X,//)                                               00000880
C                                                                        00000890
      WRITE(6,100)                                                       00000900
C                                                                        00000910
      DO 1002 I=3,5                                                      00000920
      WRITE(6,110) (NAME(I,K), K=1,5),(DIST(I,J), J=1,7)                 00000930
 1002 CONTINUE                                                           00000940
C                                                                        00000950
      WRITE(6,130)                                                       00000960
  130 FORMAT(//,16X,'COMPETITOR PARAMETERS:',//)                         00000970
C                                                                        00000980
      WRITE(6,100)                                                       00000990
C                                                                        00001000
      WRITE(6,110) (NAME(6,K), K=1,5),(DIST(6,J), J=1,7)                 00001010
C                                                                        00001020
C                                                                        00001030
C                                                                        00001040
C    DETERMINE LAMBDA PARAMETERS.                                        00001050
C                                                                        00001060
C                                                                        00001070
C                                                                        00001080
      CIER=0                                                             00001090
      WRITE(6,140)                                                       00001100
  140 FORMAT(//,16X,'LAMBDA PARAMETERS:',///,20X,'DISTRIBUTION',8X,      00001110
     $ 'LAMBDA 1',2X,'LAMBDA 2',2X,'LAMBDA 3',2X,'LAMBDA 4',/)           00001120
```

170

```
C                                                                00001130
      DO 1003 I=1,6                                               00001140
      CALL FIND(DIST(I,6),DIST(I,7),I,IER,NIE)                    00001150
      IF (IER.EQ.1) GO TO 160                                     00001160
      IF (NIE.EQ.1) GO TO 162                                     00001170
C                                                                00001180
      WRITE(6,150) (NAME(I,K),K=1,5),(LAM(I,J),J=1,4)             00001190
  150 FORMAT(18X,5A4,4F10.6)                                      00001200
C                                                                00001210
      GO TO 1003                                                  00001220
  160 CIER=CIER+1                                                 00001230
C                                                                00001240
      WRITE(6,161) (NAME(I,K),K=1,5)                              00001250
  161 FORMAT(18X,5A4,2X,'LAMBDA VALUES OUT OF RANGE.   EXECUTION CONTINUE00001260
     $S.')                                                        00001270
C                                                                00001280
      GO TO 1003                                                  00001290
C                                                                00001300
  162 WRITE(6,163) (NAME(I,K),K=1,5)                              00001310
  163 FORMAT(18X,5A4,2X,'ALPHA3 AND ALPHA4 NOT INPUT. EXECUTION CONTINUE00001320
     $S.')                                                        00001330
C                                                                00001340
 1003 CONTINUE                                                    00001350
C                                                                00001360
      IF (CIER.GE.1) GO TO 165                                    00001370
      GO TO 170                                                   00001380
C                                                                00001390
  165 WRITE(6,166)                                                00001400
  166 FORMAT(//,18X,'PROGRAM HAS ABNORMALLY TERMINATED SINCE LAMBDA VALU00001410
     $ES FOR',/,18X,'ALL DISTRIBUTIONS SPECIFIED WERE NOT FOUND.')  00001420
C                                                                00001430
      GO TO 2000                                                  00001440
C                                                                00001450
C                                                                00001460
C                                                                00001470
C   DO-LOOP FOR THE NUMBER OF EXPERIMENTS.                       00001480
C                                                                00001490
C                                                                00001500
C                                                                00001510
  170 DO 1999 NE=1,NEXPMT                                         00001520
C                                                                00001530
C                                                                00001540
C                                                                00001550
C   DETERMINE WHEN M* WILL BE MODIFIED WITH RESPECT TO BACKLOG OF WORK. 00001560
C                                                                00001570
C                                                                00001580
C                                                                00001590
      IF (EXOPT2.EQ.0) GO TO 2002                                00001600
      IF (EXOPT2.EQ.1) GO TO 2004                                00001610
      IF (EXOPT2.EQ.2) GO TO 2006                                00001620
      IF (EXOPT2.EQ.3) GO TO 2008                                00001630
      IF (EXOPT2.EQ.4) GO TO 2010                                00001640
      IF (EXOPT2.EQ.5) GO TO 2012                                00001650
      IF (EXOPT2.GE.6) GO TO 2014                                00001660
 2002 UPROA 0.                                                   00001670
      UPROB=0.                                                   00001680
```

```
          GO TO 175                                                  00001690
2004  UPROA=.5                                                       00001700
      UPROB=.5                                                       00001710
          GO TO 175                                                  00001720
2006  UPROA=.1                                                       00001730
      UPROB=.1                                                       00001740
          GO TO 175                                                  00001750
2008  UPROA=.2                                                       00001760
      UPROB=.2                                                       00001770
          GO TO 175                                                  00001780
2010  UPROA=.3                                                       00001790
      UPROB=.1                                                       00001800
          GO TO 175                                                  00001810
2012  UPROA=.3                                                       00001820
      UPROB=.3                                                       00001830
          GO TO 175                                                  00001840
2014  UPROA=.5                                                       00001850
      UPROB=.1                                                       00001860
C                                                                    00001870
C                                                                    00001880
C                                                                    00001890
C   DO-LOOP FOR THE NUMBER OF SAMPLES TO BE RUN.                     00001900
C                                                                    00001910
C                                                                    00001920
C                                                                    00001930
  175 DO 1004 NS=1,NSAMPL                                            00001940
C                                                                    00001950
      READ(5,30) KB,CB,WMAX,OPTJS                                    00001960
   30 FORMAT(4E10.4)                                                 00001970
C                                                                    00001980
C                                                                    00001990
C                                                                    00002000
C   CLEAR ARRAYS PROF1 AND PROF2 FROM THE PREVIOUS SAMPLE.           00002010
C                                                                    00002020
C                                                                    00002030
C                                                                    00002040
      DO 1050 PN=1,200                                               00002050
      DO 1051 I=1,9                                                  00002060
      PROF1(PN,I)=0.                                                 00002070
      PROF2(PN,I)=0.                                                 00002080
 1051 CONTINUE                                                       00002090
 1050 CONTINUE                                                       00002100
C                                                                    00002110
C                                                                    00002120
C                                                                    00002130
C   INITIALIZE POINTERS FOR DISK STORAGE.                            00002140
C                                                                    00002150
C                                                                    00002160
C                                                                    00002170
      DO 1098 I=8,14                                                 00002180
      REWIND I                                                       00002190
 1098 CONTINUE                                                       00002200
C                                                                    00002210
C                                                                    00002220
C                                                                    00002230
C   INITIALIZE VARIABLES.                                            00002240
```

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```
C                                                                   00002250
C                                                                   00002260
C                                                                   00002270
      W1=WMAX                                                       00002280
      W2=WMAX                                                       00002290
      U1=0.                                                         00002300
      U2=0.                                                         00002310
      BONDCP=RATBC*WMAX                                             00002320
C                                                                   00002330
C                                                                   00002340
C                                                                   00002350
C   DETERMINE POINTS ON W VERSUS U CURVE WHERE MARKUP WILL BE MODIFIED.  00002360
C                                                                   00002370
C                                                                   00002380
C                                                                   00002390
      INCR=INT(BONDCP/1000.)                                        00002400
      IF (INCR.LE.0) INCR=1                                         00002410
      IBOND=INT(BONDCP)                                             00002420
C                                                                   00002430
      TESTW1=0.                                                     00002440
      DO 1097 U=1,IBOND,INCR                                        00002450
      W=CB*FLOAT(U)*2.71828**(-KB*FLOAT(U))                         00002460
      IF (WMAX.LE.W) GO TO 171                                      00002470
      TESTW2=W                                                      00002480
      IF (TESTW2.LE.TESTW1) GO TO 171                               00002490
      TESTW1=TESTW2                                                 00002500
      GO TO 1097                                                    00002510
  171 A=FLOAT(U)                                                    00002520
      GO TO 172                                                     00002530
 1097 CONTINUE                                                      00002540
C                                                                   00002550
  172 TESTW1=0.                                                     00002560
      DO 1096 I=1,1000                                              00002570
      IF (I.EQ.1) GO TO 173                                         00002580
      IBOND=IBOND-INCR                                              00002590
  173 U=IBOND                                                       00002600
      W=CB*FLOAT(U)*2.71828**(-KB*FLOAT(U))                         00002610
      IF (W.GE.WMAX) GO TO 174                                      00002620
      TESTW2=W                                                      00002630
      IF (TESTW2.LE.TESTW1) GO TO 174                               00002640
      TESTW1=TESTW2                                                 00002650
      GO TO 1096                                                    00002660
  174 B=FLOAT(U)                                                    00002670
      GO TO 2052                                                    00002680
 1096 CONTINUE                                                      00002690
C                                                                   00002700
 2052 IF (B.LE.A) B=A                                               00002710
      MAXPRO=B-A                                                    00002720
      APRIME=A+UPROA*MAXPRO                                         00002730
      BPRIME=B-UPROB*MAXPRO                                         00002740
      IF (APRIME.LE.0.) APRIME=0.                                   00002750
      IF (BPRIME.GE.BONDCP) BPRIME=BONDCP                           00002760
      CHCKU=A+(MAXPRO*.5)                                           00002770
      TINCR=5.*FLOAT(INCR)                                          00002780
      TESTAB=BPRIME-APRIME                                          00002790
      IF (TESTAB.LE.TINCR) APRIME=BPRIME                            00002800
```

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```
      CHCK=CHCKU                                                     00002810
C                                                                    00002820
C                                                                    00002830
C                                                                    00002840
C  INITIALIZE COUNTERS FOR SUMMARY REPORT.                           00002850
C                                                                    00002860
C                                                                    00002870
C                                                                    00002880
      CJBSIZ=0.                                                      00002890
C                                                                    00002900
      TAMD1=0.                                                       00002910
      GPP1=0.                                                        00002920
      CW1=0.                                                         00002930
      CU1=0.                                                         00002940
      CACCT1=0.                                                      00002950
      CTEC1=0.                                                       00002960
      CJS1=0.                                                        00002970
      CBID1=0.                                                       00002980
      CAWC1=0.                                                       00002990
      CAC1=0.                                                        00003000
      CGP1=0.                                                        00003010
      CEC1=0.                                                        00003020
      COHC1=0.                                                       00003030
      CNP1=0.                                                        00003040
      CCJBS1=0.                                                      00003050
      CCBID1=0.                                                      00003060
      CPGP1=0.                                                       00003070
C                                                                    00003080
      TAMD2=0.                                                       00003090
      GPP2=0.                                                        00003100
      CW2=0.                                                         00003110
      CU2=0.                                                         00003120
      CACCT2=0.                                                      00003130
      CTEC2=0.                                                       00003140
      CJS2=0.                                                        00003150
      CBID2=0.                                                       00003160
      CAWC2=0.                                                       00003170
      CAC2=0.                                                        00003180
      CGP2=0.                                                        00003190
      CEC2=0.                                                        00003200
      COHC2=0.                                                       00003210
      CNP2=0.                                                        00003220
      CCJBS2=0.                                                      00003230
      CCBID2=0.                                                      00003240
      CPGP2=0.                                                       00003250
C                                                                    00003260
C                                                                    00003270
C                                                                    00003280
C  PRINT HEADINGS IF USER DESIRES COMPLETE TABULATION OF RESULTS.    00003290
C                                                                    00003300
C                                                                    00003310
C                                                                    00003320
      IF (PRNOP1.EQ.2) WRITE(6,180) NS                               00003330
  180 FORMAT('1',//,38X,61('*'),/,38X,'*',59X,'*',/,38X,'*',5X,'COMPLETE00003340
     $ TABULATION OF RESULTS FOR SAMPLE NO.',I4,5X,'*',/,38X,'*',59X, 00003350
     $'*',/,38X,61('*'))                                             00003360
```

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       IF (PRNOP1.EQ.3) WRITE(6,182) NS                                00003370
  182 FORMAT('1',//,30X,71('*'),//,30X,'*',69X,'*',//,30X,'*',5X,'COMPLETE00003380
     $ TABULATION OF BID OPPORTUNITIES FOR SAMPLE NO.',I4,5X,'*',//,30X, 00003390
     $'*',69X,'*',//,30X,71('*')))                                      00003400
       IF (PRNOP1.EQ.2) WRITE(6,181)                                    00003410
  181 FORMAT(////, 4X,'PROJ #',3X,'EST COST',4X,'BID M*',4X,'BID M**',5X,00003420
     $'AWC M*',4X,'AWC M**',4X,'LOST M*',4X,'LOST M**',2X,'GRS PROFIT',  00003430
     $2X,'COST EST',3X,'COST OH',3X,'NET PROFIT',//)                     00003440
C                                                                        00003450
C                                                                        00003460
C                                                                        00003470
C  INITIALIZE COUNTERS FOR TOTAL NUMBER OF JOB OPPORTUNITIES, TOTAL      00003480
C  NUMBER OF JOBS BID AT M*, TOTAL NUMBER OF JOBS WON AT M*, TOTAL       00003490
C  NUMBER OF JOBS BID AT M**, AND TOTAL NUMBER OF JOBS WON AT M**.       00003500
C                                                                        00003510
C                                                                        00003520
C                                                                        00003530
  190 CNJOBS=0                                                           00003540
      CBIDM=0                                                            00003550
      CWONM=0                                                            00003560
      CBIDMM=0                                                           00003570
      CWONMM=0                                                           00003580
      CCOMM=0                                                            00003590
      CCOMMM=0                                                           00003600
      CCWONM=0                                                           00003610
      CCWNMM=0                                                           00003620
      CUW=0                                                              00003630
      INJMON=0                                                           00003640
C                                                                        00003650
C                                                                        00003660
C                                                                        00003670
C  DO-LOOP FOR THE NUMBER OF MONTHS PER SAMPLE.                          00003680
C                                                                        00003690
C                                                                        00003700
C                                                                        00003710
      DO 1005 NM=1,NMONTH                                                00003720
      IF (PRNOP1.EQ.3) WRITE(6,1500) NM                                 00003730
 1500 FORMAT(/////,1X,132('-'),//,38X,'COMPLETE TABULATION OF BID OPPORTUN00003740
     $ITIES FOR MONTH:',1X,I3,/,1X,132('-'),//)                         00003750
C                                                                        00003760
C                                                                        00003770
C                                                                        00003780
C  DETERMINE THE NUMBER OF BID OPPORTUNITIES FOR THE MONTH.             00003790
C                                                                        00003800
C                                                                        00003810
C                                                                        00003820
      P1=DRAND1(ISEED1)                                                  00003830
      NJOBS=INT(ROFF(DIST(1,4),DIST(1,5),LAM(1,1),LAM(1,2),LAM(1,3),     00003840
     $LAM(1,4),P1)+.5)                                                   00003850
      IF (NM.EQ.1) NJOBS=500                                            00003860
C                                                                        00003870
C                                                                        00003880
C                                                                        00003890
C  STORE THE VALUE FOR THE NUMBER OF BID OPPORTUNITIES ON DISK FOR LATER00003900
C  ANALYSIS.  PRINT VALUE IF COMPLETE TABULATION OF BID OPPORTUNITIES   00003910
C  SPECIFIED.                                                           00003920
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C                                                                 00003930
C                                                                 00003940
C                                                                 00003950
      IF (NM.NE.1) WRITE(8,1900) NJOBS                            00003960
 1900 FORMAT(I3)                                                  00003970
C                                                                 00003980
C                                                                 00003990
      IF (PRNOP1.EQ.3) WRITE(6,1501) NJOBS                        00004000
 1501 FORMAT(1X,'NUMBER OF BID OPPORTUNITIES:',1X,I3)             00004010
C                                                                 00004020
C                                                                 00004030
C                                                                 00004040
C  DO-LOOP FOR EXAMINING EACH OF THE BID OPPORTUNITIES FOR THE MONTH. 00004050
C                                                                 00004060
C                                                                 00004070
C                                                                 00004080
      IF (NJOBS.LE.0) GO TO 2520                                  00004090
      DO 1006 NJ=1,NJOBS                                          00004100
      IF (NM.EQ.1) INJMON=INJMON+1                                00004110
      IF (NM.NE.1) CNJOBS=CNJOBS+1                                00004120
C                                                                 00004130
C                                                                 00004140
C                                                                 00004150
C  DETERMINE THE ESTIMATED JOB SIZE.                              00004160
C                                                                 00004170
C                                                                 00004180
C                                                                 00004190
      PRONUM=FLOAT(NM)+FLOAT(NJ)/1000.                            00004200
      NBM=0                                                       00004210
      NBMM=0                                                      00004220
  201 P2=DRAND1(ISEED2)                                           00004230
      JOBSIZ=ROFP(DIST(2,4),DIST(2,5),LAM(2,1),LAM(2,2),LAM(2,3), 00004240
     $LAM(2,4),P2)                                                00004250
      IF (JOBSIZ.LE.0.) GO TO 201                                 00004260
      IF (EXOPT1.EQ.1) JOBSIZ=OPTJS                               00004270
      IF (EXOPT1.NE.1) OPTJS=0.                                   00004280
      IF (NM.NE.1) CJBSIZ=CJBSIZ+JOBSIZ                           00004290
C                                                                 00004300
C                                                                 00004310
C                                                                 00004320
C  STORE THE VALUE FOR THE ESTIMATED JOB SIZE ON DISK FOR LATER   00004330
C  ANALYSIS.                                                      00004340
C                                                                 00004350
C                                                                 00004360
C                                                                 00004370
      IF (NM.NE.1) WRITE(9,1905) JOBSIZ                           00004380
 1905 FORMAT(E10.4)                                               00004390
C                                                                 00004400
C                                                                 00004410
C                                                                 00004420
C  DETERMINE THE COST OF ESTIMATING FOR THE JOB BASED ON JOB SIZE. 00004430
C                                                                 00004440
C                                                                 00004450
C                                                                 00004460
      P4=DRAND1(ISEED4)                                           00004470
      ESTCST=DIST(4,1)+DIST(4,2)*(JOBSIZ**DIST(4,3))+ROFP(DIST(4,4), 00004480
```

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     $DIST(4,5),LAM(4,1),LAM(4,2),LAM(4,3),LAM(4,4),P4)                00004490
C                                                                       00004500
C                                                                       00004510
C                                                                       00004520
C DETERMINE THE OVERHEAD COST FOR THE JOB BASED ON THE JOB SIZE.        00004530
C                                                                       00004540
C                                                                       00004550
C                                                                       00004560
     P5=DRAND1(ISEED5)                                                  00004570
     OHCOST=DIST(5,1)+DIST(5,2)*(JOBSIZ**DIST(5,3))+ROFP(DIST(5,4),     00004580
    $DIST(5,5),LAM(5,1),LAM(5,2),LAM(5,3),LAM(5,4),P5)                  00004590
C                                                                       00004600
C                                                                       00004610
C                                                                       0C004620
C DETERMINE THE SUBJECT CONTRACTOR'S MARKUP.  THE PARAMETERS FOR THIS   0C004630
C DISTRIBUTION WERE OBTAINED USING DOUG LUDOLPH'S MAG3 PROGRAM.  MARKUP000004640
C IS M*.                                                                00004650
C                                                                       00004660
C                                                                       00004670
C                                                                       00004680
     SMRKUP=DIST(3,1)+DIST(3,2)*(JOBSIZ**DIST(3,3))                     00004690
     SUBBID=JOBSIZ+SMRKUP*JOBSIZ                                        00004700
C                                                                       00004710
C                                                                       00004720
C                                                                       00004730
C DETERMINE A MODIFIED MARKUP, M**, THAT ACCOUNTS FOR THE PRESENT       00004740
C BACKLOG OF WORK.                                                      00004750
C                                                                       00004760
C                                                                       00004770
C                                                                       00004780
     PROJU3=U2+JOBSIZ                                                   00004790
C                                                                       00004800
     IF (BPRIME.EQ.APRIME) GO TO 2218                                   00004810
     IF (U2.LT.APRIME) GO TO 2222                                       00004820
     IF (U2.GE.APRIME.AND.U2.LE.BPRIME) GO TO 2226                      00004830
     IF (U2.GT.BPRIME) GO TO 2230                                       00004840
C                                                                       00004850
 2218 IF (U2.LT.APRIME) GO TO 2220                                      00004860
     IF (U2.EQ.APRIME) GO TO 2228                                       00004870
     IF (U2.GT.APRIME) GO TO 2230                                       00004880
C                                                                       00004890
 2222 IF (PROJU3.LE.BPRIME) GO TO 2220                                  00004900
     IF (PROJU3.GT.BPRIME) GO TO 2224                                   00004910
C                                                                       00004920
 2226 IF (PROJU3.LE.BPRIME) GO TO 2228                                  00004930
     IF (PROJU3.GT.BPRIME) GO TO 2230                                   00004940
C                                                                       00004950
 2220 MODMUP=SMRKUP+((U2-APRIME)/(RATMMA))                              00004960
     GO TO 2240                                                         00004970
C                                                                       00004980
 2224 IF (RATMMB.LT.0.) NBMM=1                                          00004990
     MODMUP=SMRKUP+((U2-APRIME)/(RATMMA))+((PROJU3-BPRIME)/(RATMMB))    00005000
     GO TO 2240 .                                                       00005010
C                                                                       00005020
 2228 MODMUP=SMRKUP                                                     00005030
     GO TO 2240                                                         00005040
```

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C                                                                  00005050
 2230 IF (RATMMB.LT.0.) NBMM=1                                      00005060
      MODMUP=SMRKUP+((PROJU3-BPRIME)/(RATMMB))                      00005070
C                                                                  00005080
 2240 IF (U2.GE.CHCKU) CHCKU=0.                                     00005090
      IF (U2.LE.CHCKU) MODMUP=SMRKUP                                00005100
C                                                                  00005110
      MSBBID=JOBSIZ+MODMUP*JOBSIZ                                   00005120
C                                                                  00005130
C                                                                  00005140
C                                                                  00005150
C   DETERMINE COMPETITOR'S MARKUP.                                 00005160
C                                                                  00005170
C                                                                  00005180
C                                                                  00005190
      P6=DRAND2(ISEED6)                                            00005200
      CMRKUP=DIST(6,1)+DIST(6,2)*(JOBSIZ**DIST(6,3))+ROFP(DIST(6,4),DIST00005210
     $(6,5),LAM(6,1),LAM(6,2),LAM(6,3),LAM(6,4),P6)                00005220
      COMBID=JOBSIZ+CMRKUP*JOBSIZ                                   00005230
      IF (U2.LE.CHCKU) COMBID=SUBBID+.1E-03*SUBBID                  00005240
C                                                                  00005250
C                                                                  00005260
C                                                                  00005270
C   TEST THE SUITABILITY OF THE OPPORTUNITY WITH RESPECT TO THE    00005280
C   USER SPECIFIED CONSTRAINTS ON JOB SIZE.                        00005290
C                                                                  00005300
C                                                                  00005310
C                                                                  00005320
      BNB=1.0*BONDCP                                                00005330
      PROJU1=U1+JOBSIZ                                              00005340
      PROJU2=U2+JOBSIZ                                              00005350
      IF (JOBSIZ.LT.MINJS.OR.JOBSIZ.GT.MAXJS.OR.PROJU1.GT.BONDCP.OR. 00005360
     $JOBSIZ.GT.BNB) NBM=1                                         00005370
      IF (JOBSIZ.LT.MINJS.OR.JOBSIZ.GT.MAXJS.OR.PROJU2.GT.BONDCP.OR. 00005380
     $JOBSIZ.GT.BNB) NBMM=1                                        00005390
      IF (NBM.EQ.0.AND.NM.NE.1) CBIDM=CBIDM+1                       00005400
      IF (NBM.EQ.1) SUBBID-                                         00005410
      IF (NBMM.EQ.0.AND.NM.NE.1) CBIDMM=CBIDMM+1                    00005420
      IF (NBMM.EQ.1) MSBBID=0.                                      00005430
C                                                                  00005440
C                                                                  00005450
C                                                                  00005460
C   DETERMINE THE PERCEIVED POTENTIAL AWARDED DOLLARS AND GROSS PROFITS 00005470
C   IN THE MARKET WITH THE SUBJECT CONTRACTOR BIDDING AT M* AND M**. 00005480
C                                                                  00005490
C                                                                  00005500
C                                                                  00005510
      IF (NM.EQ.1) GO TO 2532                                       00005520
      IF (SUBBID.LE.COMBID.AND.SUBBID.NE.0.) GO TO 210             00005530
      AMD1 COMBID                                                   00005540
      PP1=CMRKUP*JOBSIZ                                             00005550
      GO TO 211                                                     00005560
  210 AMD1=SUBBID                                                   00005570
      PP1=SMRKUP*JOBSIZ                                             00005580
  211 TAMD1=TAMD1+AMD1                                              00005590
      GPP1=GPP1+PP1                                                 00005600
```

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      IF (MSBBID.LE.COMBID.AND.MSBBID.NE.O.) GO TO 212            00005610
      AMD2=COMBID                                                 00005620
      PP2=CMRKUP*JOBSIZ                                           00005630
      GO TO 213                                                   00005640
  212 AMD2=MSBBID                                                 00005650
      PP2=MODMUP*JOBSIZ                                           00005660
  213 TAMD2=TAMD2+AMD2                                            00005670
      GPP2=GPP2+PP2                                               00005680
C                                                                 00005690
C                                                                 00005700
C                                                                 00005710
C  UPDATE CUMULATIVE COST OF ESTIMATING FOR ALL OPPORTUNITIES BID BY THE00005720
C  SUBJECT CONTRACTOR.                                           00005730
C                                                                 00005740
C                                                                 00005750
C                                                                 00005760
 2532 IF (NBM.EQ.0) CTEC1=CTEC1+ESTCST                           00005770
      IF (NBMM.EQ.0) CTEC2=CTEC2+ESTCST                          00005780
C                                                                 00005790
C                                                                 00005800
C                                                                 00005810
C  PRINT VALUES IF COMPLETE TABULATION OF BID OPPORTUNITIES SPECIFIED.  00005820
C                                                                 00005830
C                                                                 00005840
C                                                                 00005850
      IF (PRNOP1.EQ.3) GO TO 220                                 00005860
      GO TO 240                                                  00005870
  220 WRITE(6,1502) NJ,JOBSIZ                                    00005880
 1502 FORMAT(////,1X,'BID OPPORTUNITY NUMBER:',1X,I3,/,1X,27('-'),//, 00005890
     $3X,'ESTIMATED COST:',1X,E10.4)                             00005900
      IF (NBM.EQ.1.AND.NBMM.EQ.1) GO TO 225                      00005910
      WRITE(6,1503) ESTCST                                       00005920
 1503 FORMAT(3X,'COST OF ESTIMATING:',1X,E10.4)                  00005930
      WRITE(6,1504) OHCOST                                       00005940
 1504 FORMAT(3X,'COST OF OVERHEAD:',1X,E10.4)                    00005950
      IF (NBM.EQ.1) GO TO 225                                    00005960
      GO TO 226                                                  00005970
  225 WRITE(6,1522)                                              00005980
 1522 FORMAT(//,3X,'THE PROJECT WAS NOT BID BY THE SUBJECT CONTRACTOR AT00005990
     $ M*  DUE TO COMPANY CONSTRAINTS.',/,3X,'THE PROJECT WAS EITHER LES00006000
     $S THAN MINIMUM OR GREATER THAN MAXIMUM JOB SIZE NORMALLY BID',/, 00006010
     $3X,'OR THE PROJECTED BACKLOG IF WON WOULD HAVE EXCEEDED BONDING CA00006020
     $PACITY.')                                                  00006030
      GO TO 227                                                  00006040
  226 WRITE(6,1580) U1                                           00006050
 1580 FORMAT(/,3X,'CURRENT BACKLOG OF WORK FOR M*:',1X,E10.4)    00006060
      WRITE(6,1505) SMRKUP                                       00006070
 1505 FORMAT(3X,'MARKUP AT M*:',1X,E10.4)                        00006080
      WRITE(6,1506) SUBBID                                       00006090
 1506 FORMAT(1X,'*',1X,'BID AT M*:',1X,E10.4)                    00006100
  227 IF (NBMM.EQ.1) GO TO 230                                   00006110
      GO TO 235                                                  00006120
  230 WRITE(6,1527)                                              00006130
 1527 FORMAT(//,3X,'THE PROJECT WAS NOT BID BY THE SUBJECT CONTRACTOR AT00006140
     $ M** DUE TO COMPANY CONSTRAINTS.',/,3X,'THE PROJECT WAS EITHER LES00006150
     $S THAN MINIMUM OR GREATER THAN MAXIMUM JOB SIZE NORMALLY BID',/, 00006160
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          $3X,'OR THE PROJECTED BACKLOG IF WON WOULD HAVE EXCEEDED BONDING CA00006170
          $FACITY.')                                                      00006180
          GO TO 236                                                       00006190
      235 WRITE(6,1507) U2                                                00006200
     1507 FORMAT(/,3X,'CURRENT BACKLOG OF WORK FOR M**:',1X,E10.4)         00006210
          WRITE(6,1508) MODMUP                                            00006220
     1508 FORMAT(3X,'MARKUP AT M**:',1X,E10.4)                            00006230
          WRITE(6,1509) MSBBID                                            00006240
     1509 FORMAT(1X,'*',1X,'BID AT M**:',1X,E10.4)                        00006250
      236 WRITE(6,1511) CMRKUP                                            00006260
     1511 FORMAT(/,3X,'COMPETITOR MARKUP:',1X,E10.4)                      00006270
          WRITE(6,1512) COMBID                                            00006280
     1512 FORMAT(1X,'*',1X,'COMPETITOR BID:',1X,E10.4)                    00006290
    C                                                                     00006300
    C                                                                     00006310
    C                                                                     00006320
    C  DETERMINE IF THE SUBJECT CONTRACTOR WINS THE JOB BIDDING AT M*.    00006330
    C                                                                     00006340
    C                                                                     00006350
    C                                                                     00006360
      240 IF (SUBBID.LE.COMBID.AND.SUBBID.NE.0.) GO TO 250                00006370
          GO TO 400                                                       00006380
    C                                                                     00006390
    C                                                                     00006400
    C                                                                     00006410
    C  THE SUBJECT JOB HAS BEEN WON USING M*.  ASSIGN THE PROJECT NUMBER, 00006420
    C  JOB SIZE AND BID TO THE ARRAY PROF1.                              00006430
    C                                                                     00006440
    C                                                                     00006450
    C                                                                     00006460
      250 IF (NM.NE.1) CWONM=CWONM+1                                      00006470
          DO 1007 PN=1,200                                               00006480
          IF (PROF1(PN,1).EQ.0.) GO TO 260                               00006490
          GO TO 1007                                                     00006500
      260 PROF1(PN,1)=PRONUM                                             00006510
          PROF1(PN,2)=JOBSIZ                                             00006520
          PROF1(PN,3)=SUBBID                                             00006530
          PROF1(PN,7)=ESTCST                                             00006540
          PROF1(PN,8)=OHCOST                                             00006550
    C                                                                     00006560
    C                                                                     00006570
    C                                                                     00006580
    C  PRINT VALUES ASSIGNED TO ARRAY PROF1 IF COMPLETE TABULATION OF BID 00006590
    C  OPPORTUNITIES IS SPECIFIED.                                       00006600
    C                                                                     00006610
    C                                                                     00006620
    C                                                                     00006630
          IF (PRNOP1.EQ.3) WRITE(6,1513) PN,PN,PROF1(PN,1),PN,PROF1(PN,2),PN00006640
          $,PROF1(PN,3),PN,PROF1(PN,4),PN,PROF1(PN,5),PN,PROF1(PN,6),PN, 00006650
          $PROF1(PN,7),PN,PROF1(PN,8),PN,PROF1(PN,9)                     00006660
     1513 FORMAT(/,1X,'THE PROJECT WAS AWARDED TO THE SUBJECT CONTRACTOR BID00006670
          $DING AT M*',/,1X,'AND LOADED IN ARRAY PROF1 IN ROW',1X,I3,/,3X, 00006680
          $'PROF1(',I3,',1):',1X,F7.3,/,3X,'PROF1(',I3,',2):',1X,E10.4,/,3X, 00006690
          $'PROF1(',I3,',3):',1X,E10.4,/,3X,'PROF1(',I3,',4):',1X,E10.4,/,3X,00006700
          $'PROF1(',I3,',5):',1X,E10.4,/,3X,'PROF1(',I3,',6):',1X,E10.4,/,3X,00006710
          $'PROF1(',I3,',7):',1X,E10.4,/,3X,'PROF1(',I3,',8):',1X,E10.4,/,  00006720
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      $3X,'PROF1(',I3,',9):',1X,E10.4)                              00006730
         GO TO 280                                                   00006740
 1007 CONTINUE                                                       00006750
C                                                                    00006760
C                                                                    00006770
C                                                                    00006780
C  PRINT THE FOLLOWING MESSAGE AND ALL VALUES IN ARRAY PROF1 IF AN   00006790
C  OVERFLOW OCCURS.                                                  00006800
C                                                                    00006810
C                                                                    00006820
C                                                                    00006830
      WRITE(6,270) NS                                                00006840
  270 FORMAT('1',28X,81('*'),/,28X,'THE SIZE OF ARRAY PROF1 AS SPECIFIED00006850
     $ IS INADEQUATE FOR SAMPLE NO.',I3,1X,'AND AN',/,28X,'OVERFLOW HAS 00006860
     $OCCURRED.  THIS ARRAY CONTAINS ALL PROJECTS THAT HAVE BEEN WON',  00006870
     $ /,28X,'BUT ARE NOT COMPLETE.  PRIOR TO CHANGING THE SIZE OF THE A00006880
     $RRAY, THE USER SHOULD',/,28X,'DETERMINE IF, FOR ALL USER SPECIFIED00006890
     $ PARAMETERS, IT IS LIKELY THAT GREATER',/,28X,'THAN 30 PROJECTS W00006900
     $OULD BE BACKLOGGED AT ANY GIVEN TIME.  DATA STORED IN THE ARRAY',/,00006910
     $29X,' IS PRINTED BELOW FOR ANALYSIS.  IF THE USER DETERMINES THAT I00006920
     $T IS LIKELY THAT',/,28X,'GREATER THAN 30 PROJECTS MAY BE BACKLOGGE00006930
     $D, CHANGE THE DIMENSION STATEMENT FOR',/,28X,'THE PROFIT ARRAYS TO00006940
     $, FOR EXAMPLE, PROF1(220,9) AND PROF2(220,9).  THE USER MUST',/,   00006950
     $28X,'ALSO CHANGE THE MAXIMUM SIZE OF THE COUNTER, PN, IN 9 DO-LOOP00006960
     $S IN THE PROGRAM.',/,28X,81('*'),//)                          00006970
      WRITE(6,181)                                                   00006980
      DO 1035 PN=1,200                                               00006990
      WRITE(6,700) (PROF1(PN,I),I=1,9)                               00007000
 1035 CONTINUE                                                       00007010
      GO TO 1004                                                     00007020
  280 U1=U1+PROF1(PN,2)                                              00007030
      GO TO 410                                                      00007040
  400 IF (PRNOF1.EQ.3) WRITE(6,1521)                                 00007050
 1521 FORMAT(/,1X,'THE PROJECT WAS AWARDED TO THE COMPETITOR WITH THE SU00007060
     $BJECT CONTRACTOR BIDDING AT M*.')                             00007070
      TESTPN=PRONUM                                                  00007080
      IF (PRNOF1.EQ.2) WRITE(6,1525) PRONUM,ESTCST                  00007090
 1525 FORMAT(4X,F7.3,89X,E10.4)                                     00007100
C                                                                    00007110
C                                                                    00007120
C                                                                    00007130
C  STORE VALUES FOR ESTIMATED COST AND COMPETITOR'S BID ON DISK FOR  00007140
C  LATER ANALYSIS IF COMPETITOR WAS AWARDED THE PROJECT WITH THE SUBJECT00007150
C  CONTRACTOR BIDDING AT M*.                                         00007160
C                                                                    00007170
C                                                                    00007180
C                                                                    00007190
      IF (NM.EQ.1) GO TO 410                                         00007200
      CCWONM=CCWONM+1                                                00007210
      CCJBS1=CCJBS1+JOBSIZ                                           00007220
      CCBID1=CCBID1+COMBID                                           00007230
      CPGP1=CPGP1+CMRKUP*JOBSIZ                                      00007240
      WRITE(10,1910) JOBSIZ,COMBID,CMRKUP                           00007250
 1910 FORMAT(3E10.4)                                                00007260
C                                                                    00007270
C                                                                    00007280
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C                                                                    00007290
C   DETERMINE IF THE SUBJECT CONTRACTOR WINS THE JOB BIDDING AT A     00007300
C   MODIFIED M* CALLED M**                                            00007310
C                                                                    00007320
C                                                                    00007330
C                                                                    00007340
    410 IF (MSBBID.LE.COMBID.AND.MSBBID.NE.0.) GO TO 550             00007350
        GO TO 590                                                    00007360
C                                                                    00007370
C                                                                    00007380
C                                                                    00007390
C   THE SUBJECT JOB HAS BEEN WON USING M**. ASSIGN THE PROJECT NUMBER, 00007400
C   JOB SIZE AND BID TO THE ARRAY PROF2.                             00007410
C                                                                    00007420
C                                                                    00007430
C                                                                    00007440
    550 IF (NM.NE.1) CWONMM=CWONMM+1                                 00007450
        DO 1020 PN=1,200                                             00007460
        IF (PROF2(PN,1).EQ.0.) GO TO 560                            00007470
        GO TO 1020                                                   00007480
    560 PROF2(PN,1)=PRONUM                                           00007490
        PROF2(PN,2)=JOBSIZ                                           00007500
        PROF2(PN,3)=MSBBID                                           00007510
        PROF2(PN,7)=ESTCST                                           00007520
        PROF2(PN,8)=OHCOST                                           00007530
C                                                                    00007540
C                                                                    00007550
C                                                                    00007560
C   PRINT VALUES ASSIGNED TO ARRAY PROF2 IF COMPLETE TABULATION OF BID 00007570
C   OPPORTUNITIES IS SPECIFIED.                                      00007580
C                                                                    00007590
C                                                                    00007600
C                                                                    00007610
        IF (PRNOP1.EQ.3) WRITE(6,1713) PN,PN,PROF2(PN,1),PN,PROF2(PN,2),PN00007620
       $,PROF2(PN,3),PN,PROF2(PN,4),PN,PROF2(PN,5),PN,PROF2(PN,6),PN,    00007630
       $PROF2(PN,7),PN,PROF2(PN,8),PN,PROF2(PN,9)                     00007640
   1713 FORMAT(/,1X,'THE PROJECT WAS AWARDED TO THE SUBJECT CONTRACTOR BID00007650
       $DING AT M**',/,1X,'AND LOADED IN ARRAY PROF2 IN ROW',1X,I3,/,3X, 00007660
       $'PROF2(',I3,',1):',1X,F7.3,/,3X,'PROF2(',I3,',2):',1X,E10.4,/,3X, 00007670
       $'PROF2(',I3,',3):',1X,E10.4,/,3X,'PROF2(',I3,',4):',1X,E10.4,/,3X,00007680
       $'PROF2(',I3,',5):',1X,E10.4,/,3X,'PROF2(',I3,',6):',1X,E10.4,/,3X,00007690
       $'PROF2(',I3,',7):',1X,E10.4,/,3X,'PROF2(',I3,',8):',1X,E10.4,/,   00007700
       $3X,'PROF2(',I3,',9):',1X,E10.4)                              00007710
        GO TO 580                                                    00007720
   1020 CONTINUE                                                     00007730
C                                                                    00007740
C                                                                    00007750
C                                                                    00007760
C   PRINT THE FOLLOWING MESSAGE AND ALL VALUES IN ARRAY PROF2 IF AN   00007770
C   OVERFLOW OCCURS.                                                 00007780
C                                                                    00007790
C                                                                    00007800
C                                                                    00007810
        WRITE(6,570) NS                                              00007820
    570 FORMAT('1',28X,81('*'),/,28X,'THE SIZE OF ARRAY PROF2 AS SPECIFIED00007830
       $ IS INADEQUATE FOR SAMPLE NO.',I3,1X,'AND AN',/,28X,'OVERFLOW HAS 00007840
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AD
A092519

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      $OCCURRED.  THIS ARRAY CONTAINS ALL PROJECTS THAT HAVE BEEN WON',  00007850
      $ /,28X,'BUT ARE NOT COMPLETE.  PRIOR TO CHANGING THE SIZE OF THE A00007860
      $RRAY, THE USER SHOULD',/,28X,'DETERMINE IF, FOR ALL USER SPECIFIED00007870
      $ PARAMETERS, IT IS LIKELY THAT GREATER',/,28X,'THAN 30 PROJECTS W000007880
      $ULD BE BACKLOGGED AT ANY GIVEN TIME.  DATA STORED IN THE ARRAY',/,00007890
      $28X,'IS PRINTED BELOW FOR ANALYSIS.  IF THE USER DETERMINES THAT I00007900
      $T IS LIKELY THAT',/,28X,'GREATER THAN 30 PROJECTS MAY BE BACKLOGGE00007910
      $D, CHANGE THE DIMENSION STATEMENT FOR',/,28X,'THE PROFIT ARRAYS T000007920
      $, FOR EXAMPLE, PROF1(220,9) AND PROF2(220,9).  THE USER MUST',/,  00007930
      $28X,'ALSO CHANGE THE MAXIMUM SIZE OF THE COUNTER, PN, IN 9 DO-LOOP00007940
      $S IN THE PROGRAM.',/,28X,81('*'),//)                             00007950
          WRITE(6,181)                                                  00007960
          DO 1040 PN=1,200                                              00007970
          WRITE(6,710) (PROF2(PN,I),I=1,9)                              00007980
     1040 CONTINUE                                                      00007990
          GO TO 1004                                                    00008000
      580 U2=U2+PROF2(PN,2)                                             00008010
          GO TO 2524                                                    00008020
      590 IF (PRNOP1.EQ.3) WRITE(6,1530)                                00008030
     1530 FORMAT(/,1X,'THE PROJECT WAS AWARDED TO THE COMPETITOR WITH THE SU00008040
      $BJECT CONTRACTOR BIDDING AT M**.')                              00008050
          IF (PRONUM.EQ.TESTPN) GO TO 592                               00008060
          IF (PRNOP1.EQ.2) WRITE(6,1525) PRONUM,ESTCST                  00008070
C                                                                       00008080
C                                                                       00008090
C                                                                       00008100
C   STORE VALUES FOR ESTIMATED COST AND COMPETITOR'S BID ON DISK FOR    00008110
C   LATER ANALYSIS IF COMPETITOR WAS AWARDED THE PROJECT WITH THE SUBJECT00008120
C   CONTRACTOR BIDDING AT M**.                                          00008130
C                                                                       00008140
C                                                                       00008150
C                                                                       00008160
          IF (NM.EQ.1) GO TO 2524                                       00008170
      592 CCWNMM=CCWNMM+1                                               00008180
          CCJBS2=CCJBS2+JOBSIZ                                          00008190
          CCBID2=CCBID2+COMBID                                          00008200
          CPGP2=CPGP2+CMRKUP*JOBSIZ                                     00008210
          WRITE(11,1910) JOBSIZ,COMBID,CMRKUP                          00008220
C                                                                       00008230
C                                                                       00008240
C                                                                       00008250
     2524 IF (NM.EQ.1.AND.U1.GE.CHCKU.AND.U2.GE.CHCKU) GO TO 1005       00008260
     1006 CONTINUE                                                      00008270
C                                                                       00008280
C                                                                       00008290
C                                                                       00008300
C   THE END OF THE MONTH HAS OCCURRED.  DETERMINE THE WORK RATE THAT WAS 00008310
C   LOST DURING THE MONTH BASED ON THE BACKLOG OF WORK AT THE BEGINNING  00008320
C   OF THE MONTH.                                                       00008330
C                                                                       00008340
C                                                                       00008350
C                                                                       00008360
     2520 WL1=(WMAX-W1)*LABEQP                                          00008370
          NP=0                                                          00008380
C                                                                       00008390
C                                                                       00008400
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C                                                                       00008410
C  DO-LOOP FOR COUNTING THE NUMBER OF PROJECTS IN ARRAY PROF1.          00008420
C                                                                       00008430
C                                                                       00008440
      DO 1008 PN=1,200                                                  00008450
      IF (PROF1(PN,1).GT.0.) NP=NP+1                                    00008460
 1008 CONTINUE                                                          00008470
      IF (NP.EQ.0) GO TO 621                                           00008480
C                                                                       00008490
C                                                                       00008500
C                                                                       00008510
C  THE WORK COMPLETE AND THE WORK LOST FOR THE MONTH ARE EQUALLY        00008520
C  DISTRIBUTED TO ALL JOBS IN ARRAY PROF1.                             00008530
C                                                                       00008540
C                                                                       00008550
C                                                                       00008560
      WP1=W1/FLOAT(NP)                                                  00008570
      WLP1=WL1/FLOAT(NP)                                                00008580
      WR1=0.                                                           00008590
      WLR1=0.                                                          00008600
      CWR1=0.                                                          00008610
      CWLR1=0.                                                         00008620
C                                                                       00008630
C                                                                       00008640
C                                                                       00008650
C  PRINT VALUES IF COMPLETE TABULATION OF BID OPPORTUNITIES SPECIFIED.  00008660
C                                                                       00008670
C                                                                       00008680
C                                                                       00008690
      IF (PRNOP1.EQ.3) GO TO 595                                       00008700
      GO TO 596                                                        00008710
  595 WRITE(6,1550) NM                                                 00008720
 1550 FORMAT(///////,1X,132('-'),/,59X,'END OF MONTH:',1X,I3,/,1X,     00008730
     $132('-'),/,46X,'COMPLETE ANALYSIS OF UPDATING ARRAY PROF1',/,    00008740
     $1X,132('-'))                                                     00008750
      WRITE(6,1551) WL1                                                00008760
 1551 FORMAT(///,1X,'WORK LOST DURING THE MONTH (NOT INCLUDING MATERIALS)00008770
     $:',1X,E10.4)                                                     00008780
      WRITE(6,1552) NP                                                 00008790
 1552 FORMAT(1X,'NUMBER OF PROJECTS BACKLOGGED:',1X,I3)                00008800
      WRITE(6,1555) WP1,WLP1                                           00008810
 1555 FORMAT(1X,'PROPORTION OF WORK COMPLETE RATE TO BE EQUALLY DISTRIBU00008820
     $TED TO ALL PROJECTS:',1X,E10.4,/,1X,'PROPORTION OF WORK LOST RATE 00008830
     $TO BE EQUALLY DISTRIBUTED TO ALL PROJECTS:',1X,E10.4)            00008840
C                                                                       00008850
C                                                                       00008860
C                                                                       00008870
C  DO-LOOP FOR CHECKING IF THE ACTUAL WORK COMPLETE PLUS THE PROPORTION 00008880
C  OF THE WORK COMPLETION RATE FROM ABOVE EXCEEDS THE PROJECT SIZE.     00008890
C                                                                       00008900
C                                                                       00008910
C                                                                       00008920
  596 CAWC=0.                                                          00008930
      DO 1009 PN=1,200                                                 00008940
      IF (PROF1(PN,1).EQ.0.) GO TO 1009                               00008950
      CAWC=PROF1(PN,4)+WP1                                             00008960
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      IF (CAWC.GT.PROF1(PN,2)) GO TO 600                        00008970
      GO TO 1009                                                00008980
C                                                               00008990
C                                                               00009000
C                                                               00009010
C  DETERMINE THE PROPORTION OF THE WORK COMPLETE RATE AND THE WORK LOST 00009020
C  RATE THAT MUST BE DISTRIBUTED TO COMPLETE THE JOB.           00009030
C                                                               00009040
C                                                               00009050
C                                                               00009060
  600 WR1=PROF1(PN,2)-PROF1(PN,4)                               00009070
      WLR1=(WR1/W1)*WL1                                         00009080
C                                                               00009090
C                                                               00009100
C                                                               00009110
C  UPDATE ARRAY PROF1 WITH THE ABOVE INFORMATION.               00009120
C                                                               00009130
C                                                               00009140
C                                                               00009150
      PROF1(PN,4)=PROF1(PN,4)+WR1                               00009160
      PROF1(PN,5)=PROF1(PN,5)+WLR1                              00009170
      PROF1(PN,6)=PROF1(PN,3)-(PROF1(PN,2)+PROF1(PN,5))         00009180
      PROF1(PN,9)=PROF1(PN,6)-PROF1(PN,7)-PROF1(PN,8)           00009190
C                                                               00009200
C                                                               00009210
C                                                               00009220
C  STORE VALUES FROM ARRAY PROF1 FOR THE COMPLETED JOB ON DISK FOR 00009230
C  LATER ANALYSIS.                                              00009240
C                                                               00009250
C                                                               00009260
C                                                               00009270
      ACTCT1=PROF1(PN,2)+PROF1(PN,5)                            00009280
      CACCT1=CACCT1+ACTCT1                                      00009290
      WRITE(12,1920) PROF1(PN,2),PROF1(PN,3),ACTCT1,PROF1(PN,6),00009300
     *PROF1(PN,9)                                               00009310
 1920 FORMAT(5E10.4)                                            00009320
C                                                               00009330
C                                                               00009340
C                                                               00009350
C  UPDATE COUNTERS FOR ARRAY PROF1.                             00009360
C                                                               00009370
C                                                               00009380
C                                                               00009390
      CCOMM=CCOMM+1                                             00009400
      NP=NP-1                                                   00009410
      CWR1=CWR1+WR1                                             00009420
      CWLR1=CWLR1+WLR1                                          00009430
      CJS1=CJS1+PROF1(PN,2)                                     00009440
      CBID1=CBID1+PROF1(PN,3)                                   00009450
      CAWC1=CAWC1+PROF1(PN,4)                                   00009460
      CAC1=CAC1+PROF1(PN,5)                                     00009470
      CGP1=CGP1+PROF1(PN,6)                                     00009480
      CEC1=CEC1+PROF1(PN,7)                                     00009490
      COHC1=COHC1+PROF1(PN,8)                                   00009500
      CNP1=CNP1+PROF1(PN,9)                                     00009510
C                                                               00009520
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C                                                               00009530
C                                                               00009540
C   PRINT VALUES IF COMPLETE TABULATION OF BID OPPORTUNITIES SPECIFIED.   00009550
C                                                               00009560
C                                                               00009570
C                                                               00009580
      IF (PRNOP1.EQ.3) GO TO 598                                00009590
      GO TO 599                                                 00009600
  598 WRITE(6,1560) PROF1(PN,1),WR1,WLR1                        00009610
 1560 FORMAT(/,1X,'PROJECT',1X,F7.3,1X,'DOES NOT REQUIRE THE ENTIRE PROP00009620
     $ORTION OF THE WORK COMPLETE RATE',/,1X,'ALLOTTED TO CLOSE OUT THE 00009630
     $PROJECT.',/,3X,'WORK REQUIRED TO CLOSE OUT:',1X,E10.4,/,3X,'PROPOR00009640
     $TION OF WORK LOST ASSOCIATED WITH THE ABOVE:',1X,E10.4)   00009650
      WRITE(6,1561)                                             00009660
 1561 FORMAT(/,1X,'SUMMARY FOR THE ABOVE PROJECT AT COMPLETION:')  00009670
      WRITE(6,181)                                              00009680
      WRITE(6,700) (PROF1(PN,I),I=1,9)                          00009690
  700 FORMAT(4X,F7.3,1X,E10.4,1X,E10.4,3(12X,E10.4),3(1X,E10.4))   00009700
      GO TO 610                                                 00009710
C                                                               00009720
C                                                               00009730
C                                                               00009740
C   PRINT SUMMARY OF THE COMPLETED PROJECT IF COMPLETE TABULATION OF   00009750
C   RESULTS FOR SAMPLE SPECIFIED.                               00009760
C                                                               00009770
C                                                               00009780
C                                                               00009790
  599 IF (PRNOP1.EQ.2) WRITE(6,700) (PROF1(PN,I),I=1,9)         00009800
C                                                               00009810
C                                                               00009820
C                                                               00009830
C   DO-LOOP TO REMOVE THE COMPLETED JOB FROM THE ARRAY PROF1 AFTER THE   00009840
C   RESULTS HAVE BEEN PRINTED AND TABULATED.                    00009850
C                                                               00009860
C                                                               00009870
C                                                               00009880
  610 DO 1010 I=1,9                                             00009890
      PROF1(PN,I)=0.                                            00009900
 1010 CONTINUE                                                  00009910
 1009 CONTINUE                                                  00009920
C                                                               00009930
C                                                               00009940
C                                                               00009950
C   DETERMINE THE REMAINING PROPORTION OF THE WORK COMPLETE RATE AND   00009960
C   THE WORK LOST RATE THAT WILL BE EQUALLY DISTRIBUTED TO THE REMAINING 00009970
C   JOBS AFTER THE ABOVE JOBS IN ARRAY PROF1 ARE CLOSED OUT.    00009980
C                                                               00009990
C                                                               00010000
C                                                               00010010
      WRM1=W1-CWR1                                              00010020
      WLRM1=WL1-CWLR1                                           00010030
      IF (NP.LE.0) GO TO 620                                    00010040
      WNP1=WRM1/FLOAT(NP)                                       00010050
      WNLP1=WLRM1/FLOAT(NP)                                     00010060
C                                                               00010070
C                                                               00010080
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C                                                                    00010090
C  PRINT VALUES IF COMPLETE TABULATION OF BID OPPORTUNITIES SPECIFIED. 00010100
C                                                                    00010110
C                                                                    00010120
C                                                                    00010130
      IF (PRNOP1.EQ.3) GO TO 612                                     00010140
      GO TO 615                                                      00010150
  612 WRITE(6,1565) NP                                               00010160
 1565 FORMAT(//,1X,'NUMBER OF PROJECTS REMAINING AFTER COMPLETIONS:', 00010170
     $1X,I3)                                                         00010180
      WRITE(6,1570) WRM1, WLRM1                                      00010190
 1570 FORMAT(1X,'REMAINING WORK COMPLETE RATE:',1X,E10.4,/,1X,'REMAINING00010200
     $ WORK LOST RATE:',1X,E10.4)                                    00010210
      WRITE(6,1571) WNP1,WNLP1                                       00010220
 1571 FORMAT(1X,'PROPORTION OF REMAINING WORK COMPLETE RATE TO BE EQUALL00010230
     $Y DISTRIBUTED TO UNCOMPLETED PROJECTS:',1X,E10.4,/,1X,'PROPORTION 00010240
     $OF WORK LOST RATE TO BE EQUALLY    RIBUTED TO UNCOMPLETED PROJECT00010250
     $S:',1X,E10.4)                                                  00010260
      WRITE(6,1575)                                                  00010270
 1575 FORMAT(//,1X,'SUMMARY OF UNCOMPLETED PROJECTS IN ARRAY PROF1:')  00010280
      WRITE(6,181)                                                   00010290
C                                                                    00010300
C                                                                    00010310
C                                                                    00010320
C  UPDATE PROJECTS IN ARRAY PROF1 AND PRINT VALUES IF COMPLETE       00010330
C  TABULATION OF BID OPPORTUNITIES SPECIFIED.                        00010340
C                                                                    00010350
C                                                                    00010360
C                                                                    00010370
  615 DO 1011 PN=1,200                                               00010380
      IF (PROF1(PN,1).EQ.0.) GO TO 1011                              00010390
      PROF1(PN,4)=PROF1(PN,4)+WNP1                                   00010400
      PROF1(PN,5)=PROF1(PN,5)+WNLP1                                  00010410
      IF (PRNOP1.EQ.3) WRITE(6,700) (PROF1(PN,I),I=1,9)              00010420
 1011 CONTINUE                                                       00010430
      GO TO 625                                                      00010440
  620 W1=CWR1                                                        00010450
      GO TO 625                                                      00010460
  621 W1=0.                                                          00010470
C                                                                    00010480
C                                                                    00010490
C                                                                    00010500
C  THE END OF THE MONTH HAS OCCURRED.  DETERMINE THE WORK RATE THAT WAS 00010510
C  LOST DURING THE MONTH BASED ON THE BACKLOG OF WORK AT THE BEGINNING 00010520
C  OF THE MONTH.                                                     00010530
C                                                                    00010540
C                                                                    00010550
C                                                                    00010560
  625 WL2=(WMAX-W2)*LABEQP                                           00010570
      NP=0                                                           00010580
C                                                                    00010590
C                                                                    00010600
C                                                                    00010610
C  DO-LOOP FOR COUNTING THE NUMBER OF PROJECTS IN ARRAY PROF2.       00010620
C                                                                    00010630
C                                                                    00010640
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C                                                                      00010650
      DO 1021 PN=1,200                                                 00010660
      IF (PROF2(PN,1).GT.0.) NP=NP+1                                   00010670
 1021 CONTINUE                                                         00010680
      IF (NP.EQ.0) GO TO 712                                           00010690
C                                                                      00010700
C                                                                      00010710
C                                                                      00010720
C  THE WORK COMPLETE AND THE WORK LOST FOR THE MONTH ARE EQUALLY       00010730
C  DISTRIBUTED TO ALL JOBS IN ARRAY PROF2.                            00010740
C                                                                      00010750
C                                                                      00010760
C                                                                      00010770
      WP2=W2/FLOAT(NP)                                                 00010780
      WLP2=WL2/FLOAT(NP)                                               00010790
      WR2=0.                                                           00010800
      WLR2=0.                                                          00010810
      CWR2=0.                                                          00010820
      CWLR2=0.                                                         00010830
C                                                                      00010840
C                                                                      00010850
C                                                                      00010860
C  PRINT VALUES IF COMPLETE TABULATION OF BID OPPORTUNITIES SPECIFIED. 00010870
C                                                                      00010880
C                                                                      00010890
C                                                                      00010900
      IF (PRNOP1.EQ.3) GO TO 630                                       00010910
      GO TO 635                                                        00010920
  630 WRITE(6,1750) NM                                                 00010930
 1750 FORMAT(///,1X,132('-'),/,46X,'COMPLETE ANALYSIS OF UPDATING ARRAY 00010940
     $PROF2',/,1X,132('-'))                                           00010950
      WRITE(6,1551) WL2                                                00010960
      WRITE(6,1552) NP                                                 00010970
      WRITE(6,1555) WP2,WLP2                                           00010980
C                                                                      00010990
C                                                                      00011000
C                                                                      00011010
C  DO-LOOP FOR CHECKING IF THE ACTUAL WORK COMPLETE PLUS THE PROPORTION 00011020
C  OF THE WORK COMPLETION RATE FROM ABOVE EXCEEDS THE PROJECT SIZE.    00011030
C                                                                      00011040
C                                                                      00011050
C                                                                      00011060
  635 CAWC=0.                                                          00011070
      DO 1022 PN=1,200                                                 00011080
      IF (PROF2(PN,1).EQ.0.) GO TO 1022                               00011090
      CAWC=PROF2(PN,4)+WP2                                             00011100
      IF (CAWC.GT.PROF2(PN,2)) GO TO 650                              00011110
      GO TO 1022                                                       00011120
C                                                                      00011130
C                                                                      00011140
C                                                                      00011150
C  DETERMINE THE PROPORTION OF THE WORK COMPLETE RATE AND THE WORK LOST 00011160
C  RATE THAT MUST BE DISTRIBUTED TO COMPLETE THE JOB.                 00011170
C                                                                      00011180
C                                                                      00011190
C                                                                      00011200
```

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  650 WR2=PROF2(PN,2)-PROF2(PN,4)                                  00011210
      WLR2=(WR2/W2)*WL2                                             00011220
C                                                                  00011230
C                                                                  00011240
C                                                                  00011250
C  UPDATE ARRAY PROF2 WITH THE ABOVE INFORMATION.                  00011260
C                                                                  00011270
C                                                                  00011280
C                                                                  00011290
      PROF2(PN,4)=PROF2(PN,4)+WR2                                  00011300
      PROF2(PN,5)=PROF2(PN,5)+WLR2                                 00011310
      PROF2(PN,6)=PROF2(PN,3)-(PROF2(PN,2)+PROF2(PN,5))            00011320
      PROF2(PN,9)=PROF2(PN,6)-PROF2(PN,7)-PROF2(PN,8)              00011330
C                                                                  00011340
C                                                                  00011350
C                                                                  00011360
C  STORE VALUES FROM ARRAY PROF2 FOR THE COMPLETED JOB ON DISK FOR 00011370
C  LATER ANALYSIS.                                                 00011380
C                                                                  00011390
C                                                                  00011400
C                                                                  00011410
      ACTCT2=PROF2(PN,2)+PROF2(PN,5)                               00011420
      CACCT2=CACCT2+ACTCT2                                         00011430
      WRITE(13,1920) PROF2(PN,2),PROF2(PN,3),ACTCT2,PROF2(PN,6),   00011440
     $PROF2(PN,9)                                                  00011450
C                                                                  00011460
C                                                                  00011470
C                                                                  00011480
C  UPDATE COUNTERS FOR ARRAY PROF2.                                00011490
C                                                                  00011500
C                                                                  00011510
C                                                                  00011520
      CCOMMM=CCOMMM+1                                              00011530
      NP=NP-1                                                      00011540
      CWR2=CWR2+WR2                                                00011550
      CWLR2=CWLR2+WLR2                                             00011560
      CJS2=CJS2+PROF2(PN,2)                                        00011570
      CBID2=CBID2+PROF2(PN,3)                                      00011580
      CAWC2=CAWC2+PROF2(PN,4)                                      00011590
      CAC2=CAC2+PROF2(PN,5)                                        00011600
      CGP2=CGP2+PROF2(PN,6)                                        00011610
      CEC2=CEC2+PROF2(PN,7)                                        00011620
      COHC2=COHC2+PROF2(PN,8)                                      00011630
      CNP2=CNP2+PROF2(PN,9)                                        00011640
C                                                                  00011650
C                                                                  00011660
C                                                                  00011670
C  PRINT VALUES IF COMPLETE TABULATION OF BID OPPORTUNITIES SPECIFIED. 00011680
C                                                                  00011690
C                                                                  00011700
C                                                                  00011710
      IF (PRNOP1.EQ.3) GO TO 655                                   00011720
      GO TO 657                                                    00011730
  655 WRITE(6,1560) PROF2(PN,1),WR2,WLR2                           00011740
      WRITE(6,1561)                                                00011750
      WRITE(6,181)                                                 00011760
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      WRITE(6,710) (PROF2(PN,I),I=1,9)                          00011770
  710 FORMAT(4X,F7.3,1X,E10.4,3(12X,E10.4),4(1X,E10.4))          00011780
      GO TO 660                                                  00011790
C                                                                00011800
C                                                                00011810
C                                                                00011820
C  PRINT SUMMARY OF THE COMPLETED PROJECT IF COMPLETE TABULATION OF  00011830
C  RESULTS FOR SAMPLE SPECIFIED.                                 00011840
C                                                                00011850
C                                                                00011860
C                                                                00011870
  657 IF (PRNOP1.EQ.2) WRITE(6,710) (PROF2(PN,I),I=1,9)          00011880
C                                                                00011890
C                                                                00011900
C                                                                00011910
C  DO-LOOP TO REMOVE THE COMPLETED JOB FROM THE ARRAY PROF2 AFTER THE  00011920
C  RESULTS HAVE BEEN PRINTED AND TABULATED.                      00011930
C                                                                00011940
C                                                                00011950
C                                                                00011960
  660 DO 1023 I=1,9                                              00011970
      PROF2(PN,I)=0.                                             00011980
 1023 CONTINUE                                                   00011990
 1022 CONTINUE                                                   00012000
C                                                                00012010
C                                                                00012020
C                                                                00012030
C  DETERMINE THE REMAINING PROPORTION OF THE WORK COMPLETE RATE AND  00012040
C  THE WORK LOST RATE THAT WILL BE EQUALLY DISTRIBUTED TO THE REMAINING 00012050
C  JOBS AFTER THE ABOVE JOBS IN ARRAY PROF2 ARE CLOSED OUT.      00012060
C                                                                00012070
C                                                                00012080
C                                                                00012090
      WRM2=W2-CWR2                                               00012100
      WLRM2=WL2-CWLR2                                            00012110
      IF (NP.LE.0) GO TO 711                                     00012120
      WNP2=WRM2/FLOAT(NP)                                        00012130
      WNLP2=WLRM2/FLOAT(NP)                                      00012140
C                                                                00012150
C                                                                00012160
C                                                                00012170
C  PRINT VALUES IF COMPLETE TABULATION OF BID OPPORTUNITIES SPECIFIED.  00012180
C                                                                00012190
C                                                                00012200
C                                                                00012210
      IF (PRNOP1.EQ.3) GO TO 665                                 00012220
      GO TO 670                                                  00012230
  665 WRITE(6,1565) NP                                           00012240
      WRITE(6,1570) WRM2,WLRM2                                   00012250
      WRITE(6,1571) WNP2,WNLP2                                   00012260
      WRITE(6,1775)                                             00012270
 1775 FORMAT(//,1X,'SUMMARY OF UNCOMPLETED PROJECTS IN ARRAY PROF2:')  00012280
      WRITE(6,181)                                               00012290
C                                                                00012300
C                                                                00012310
C                                                                00012320
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C   UPDATE PROJECTS IN ARRAY PROF2 AND PRINT VAULUES IF COMPLETE         00012330
C   TABULATION OF BID OPPORTUNITIES SPECIFIED.                           00012340
C                                                                        00012350
C                                                                        00012360
C                                                                        00012370
  670 DO 1024 PN=1,200                                                   00012380
      IF (PROF2(PN,1).EQ.0.) GO TO 1024                                  00012390
      PROF2(PN,4)=PROF2(PN,4)+WNP2                                       00012400
      PROF2(PN,5)=PROF2(PN,5)+WNLP2                                      00012410
      IF (PRNOP1.EQ.3) WRITE(6,710) (PROF2(PN,I),I=1,9)                  00012420
 1024 CONTINUE                                                           00012430
      GO TO 714                                                          00012440
  711 W2=CWR2                                                            00012450
      GO TO 714                                                          00012460
  712 W2=0.                                                              00012470
C                                                                        00012480
C                                                                        00012490
C                                                                        00012500
C   UPDATE THE BACKLOG OF WORK FOR THE BEGINNING OF THE NEXT MONTH AND   00012510
C   THE WORK COMPLETION RATE FOR THE NEXT MONTH.                         00012520
C                                                                        00012530
C                                                                        00012540
C                                                                        00012550
  714 U1=U1-W1                                                           00012560
      IF (U1.LE.0.) U1=0.                                                00012570
      U2=U2-W2                                                           00012580
      IF (U2.LE.0.) U2=0.                                                00012590
      W1=CB*U1*2.71828**(-KB*U1)                                         00012600
      W2=CB*U2*2.71828**(-KB*U2)                                         00012610
      IF (W1.GT.WMAX) W1=WMAX                                            00012620
      IF (W2.GT.WMAX) W2=WMAX                                            00012630
      IF (U1.LE.CHCKU) W1=WMAX                                           00012640
      IF (U2.LE.CHCKU) W2=WMAX                                           00012650
      CUW=CUW+1                                                          00012660
      CU1=CU1+U1                                                         00012670
      CW1=CW1+W1                                                         00012680
      CU2=CU2+U2                                                         00012690
      CW2=CW2+W2                                                         00012700
C                                                                        00012710
C                                                                        00012720
C                                                                        00012730
C   STORE VALUES OF U1 AND U2 ON DISK FOR LATER ANALYSIS.               00012740
C                                                                        00012750
C                                                                        00012760
C                                                                        00012770
      WRITE(14,1930) U1,W1,U2,W2                                         00012780
 1930 FORMAT(4E10.4)                                                     00012790
 1005 CONTINUE                                                           00012800
C                                                                        00012810
C                                                                        00012820
C                                                                        00012830
C                                                                        00012840
C                                                                        00012850
C                                                                        00012860
C   DETERMINE MOMENTS, SKEWNESS AND KURTOSIS FOR THE NUMBER OF MONTHLY   00012870
C   BID OPPORTUNITIES GENERATED.                                         00012880
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C                                                                    00012890
C                                                                    00012900
C                                                                    00012910
      NMONTH=NMONTH-1                                                00012920
      DO 2200 I=1,6                                                  00012930
      GDIST(1,I)=0.                                                  00012940
 2200 CONTINUE                                                       00012950
      IF (NMONTH.EQ.0) GO TO 1033                                    00012960
      GDIST(1,1)=FLOAT(CNJOBS)/FLOAT(NMONTH)                         00012970
      REWIND 8                                                       00012980
      DO 1036 I=1,NMONTH                                             00012990
      READ(8,1900) IDATA                                             00013000
      DATA(1)=FLOAT(IDATA)                                           00013010
      XMX(1)=DATA(1)-GDIST(1,1)                                      00013020
      GDIST(1,2)=GDIST(1,2)+XMX(1)**2                                00013030
      GDIST(1,3)=GDIST(1,3)+XMX(1)**3                                00013040
      GDIST(1,4)=GDIST(1,4)+XMX(1)**4                                00013050
 1036 CONTINUE                                                       00013060
      GDIST(1,2)=GDIST(1,2)/FLOAT(NMONTH)                            00013070
      GDIST(1,3)=GDIST(1,3)/FLOAT(NMONTH)                            00013080
      GDIST(1,4)=GDIST(1,4)/FLOAT(NMONTH)                            00013090
      IF (GDIST(1,2).EQ.0.) GO TO 1034                               00013100
      GDIST(1,5)=GDIST(1,3)/GDIST(1,2)**1.5                          00013110
      GDIST(1,6)=GDIST(1,4)/GDIST(1,2)**2                            00013120
      NMONTH=NMONTH+1                                                00013130
      GO TO 1033                                                     00013140
 1034 GDIST(1,5)=0.                                                  00013150
      GDIST(1,6)=0.                                                  00013160
      NMONTH=NMONTH+1                                                00013170
C                                                                    00013180
C                                                                    00013190
C                                                                    00013200
C  DETERMINE MOMENTS, SKEWNESS AND KURTOSIS FOR THE DISTRIBUTION OF   00013210
C  ESTIMATED PROJECT SIZE GENERATED.                                 00013220
C                                                                    00013230
C                                                                    00013240
C                                                                    00013250
 1033 DO 2202 I=1,6                                                  00013260
      GDIST(2,I)=0.                                                  00013270
 2202 CONTINUE                                                       00013280
      IF (CNJOBS.EQ.0) GO TO 2500                                    00013290
      GDIST(2,1)=CJBSIZ/FLOAT(CNJOBS)                                00013300
      REWIND 9                                                       00013310
      DO 1037 I=1,CNJOBS                                             00013320
      READ(9,1905) DATA(2)                                          00013330
      XMX(2)=DATA(2)-GDIST(2,1)                                      00013340
      GDIST(2,2)=GDIST(2,2)+XMX(2)**2                                00013350
      GDIST(2,3)=GDIST(2,3)+XMX(2)**3                                00013360
      GDIST(2,4)=GDIST(2,4)+XMX(2)**4                                00013370
 1037 CONTINUE                                                       00013380
      GDIST(2,2)=GDIST(2,2)/FLOAT(CNJOBS)                            00013390
      GDIST(2,3)=GDIST(2,3)/FLOAT(CNJOBS)                            00013400
      GDIST(2,4)=GDIST(2,4)/FLOAT(CNJOBS)                            00013410
      IF (GDIST(2,2).EQ.0.) GO TO 1032                               00013420
      GDIST(2,5)=GDIST(2,3)/GDIST(2,2)**1.5                          00013430
      GDIST(2,6)=GDIST(2,4)/GDIST(2,2)**2                            00013440
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          GO TO 2500                                              00013450
  1032 GDIST(2,5)=0.                                              00013460
       GDIST(2,6)=0.                                              00013470
C                                                                 00013480
C                                                                 00013490
C                                                                 00013500
C   DETERMINE MOMENTS, SKEWNESS AND KURTOSIS FOR ESTIMATED COSTS, BIDS,  00013510
C   ACTUAL COSTS, GROSS PROFITS AND NET PROFITS FOR PROJECTS COMPLETED   00013520
C   BY THE SUBJECT CONTRACTOR BIDDING AT M*.                     00013530
C                                                                 00013540
C                                                                 00013550
C                                                                 00013560
  2500 DO 1039 I=3,7                                              00013570
       DO 1048 J=1,6                                              00013580
       GDIST(I,J)=0.                                              00013590
  1048 CONTINUE                                                   00013600
  1039 CONTINUE                                                   00013610
       IF (CCOMM.EQ.0) GO TO 2505                                 00013620
       GDIST(3,1)=CJS1/FLOAT(CCOMM)                               00013630
       GDIST(4,1)=CBID1/FLOAT(CCOMM)                              00013640
       GDIST(5,1)=CACCT1/FLOAT(CCOMM)                             00013650
       GDIST(6,1)=CGP1/FLOAT(CCOMM)                               00013660
       GDIST(7,1)=CNP1/FLOAT(CCOMM)                               00013670
       REWIND 12                                                  00013680
       DO 1041 M=1,CCOMM                                          00013690
       READ(12,1920) (DATA(I),I=3,7)                              00013700
       DO 1042 I=3,7                                              00013710
       XMX(I)=DATA(I)-GDIST(I,1)                                  00013720
       DO 1045 J=2,4                                              00013730
       GDIST(I,J)=GDIST(I,J)+XMX(I)**J                            00013740
  1045 CONTINUE                                                   00013750
  1042 CONTINUE                                                   00013760
  1041 CONTINUE                                                   00013770
       DO 1043 I=3,7                                              00013780
       DO 1044 J=2,4                                              00013790
       GDIST(I,J)=GDIST(I,J)/FLOAT(CCOMM)                         00013800
  1044 CONTINUE                                                   00013810
  1043 CONTINUE                                                   00013820
       DO 1046 I=3,7                                              00013830
       IF (GDIST(I,2).EQ.0.) GO TO 1049                           00013840
       GDIST(I,5)=GDIST(I,3)/GDIST(I,2)**1.5                      00013850
       GDIST(I,6)=GDIST(I,4)/GDIST(I,2)**2                        00013860
       GO TO 1046                                                 00013870
  1049 GDIST(I,5)=0.                                              00013880
       GDIST(I,6)=0.                                              00013890
  1046 CONTINUE                                                   00013900
C                                                                 00013910
C                                                                 00013920
C                                                                 00013930
C   DETERMINE MOMENTS, SKEWNESS AND KURTOSIS FOR ESTIMATED COST, BIDS,   00013940
C   ACTUAL COSTS, GROSS PROFITS AND NET PROFITS FOR PROJECTS COMPLETED   00013950
C   BY THE SUBJECT CONTRACTOR BIDDING AT M**.                    00013960
C                                                                 00013970
C                                                                 00013980
C                                                                 00013990
  2505 DO 1058 I=8,12                                             00014000
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      DO 1059 J=1,6                                          00014010
      GDIST(I,J)=0.                                          00014020
 1059 CONTINUE                                               00014030
 1058 CONTINUE                                               00014040
      IF (CCOMMM.EQ.0) GO TO 2506                            00014050
      GDIST(8,1)=CJS2/FLOAT(CCOMMM)                          00014060
      GDIST(9,1)=CBID2/FLOAT(CCOMMM)                         00014070
      GDIST(10,1)=CACCT2/FLOAT(CCOMMM)                       00014080
      GDIST(11,1)=CGP2/FLOAT(CCOMMM)                         00014090
      GDIST(12,1)=CNP2/FLOAT(CCOMMM)                         00014100
      REWIND 13                                              00014110
      DO 1052 M=1,CCOMMM                                     00014120
      READ(13,1920) (DATA(I),I=8,12)                         00014130
      DO 1053 I=8,12                                         00014140
      XMX(I)=DATA(I)-GDIST(I,1)                              00014150
      DO 1054 J=2,4                                          00014160
      GDIST(I,J)=GDIST(I,J)+XMX(I)**J                        00014170
 1054 CONTINUE                                               00014180
 1053 CONTINUE                                               00014190
 1052 CONTINUE                                               00014200
      DO 1055 I=8,12                                         00014210
      DO 1056 J=2,4                                          00014220
      GDIST(I,J)=GDIST(I,J)/FLOAT(CCOMMM)                    00014230
 1056 CONTINUE                                               00014240
 1055 CONTINUE                                               00014250
      DO 1057 I=8,12                                         00014260
      IF (GDIST(I,2).EQ.0.) GO TO 2501                       00014270
      GDIST(I,5)=GDIST(I,3)/GDIST(I,2)**1.5                  00014280
      GDIST(I,6)=GDIST(I,4)/GDIST(I,2)**2                    00014290
      GO TO 1057                                             00014300
 2501 GDIST(I,5)=0.                                          00014310
      GDIST(I,6)=0.                                          00014320
 1057 CONTINUE                                               00014330
C                                                            00014340
C                                                            00014350
C                                                            00014360
C   DETERMINE MOMENTS, SKEWNESS AND KURTOSIS FOR THE DISTRIBUTIONS OF  00014370
C   BACKLOG OF WORK AND WORK COMPLETE RATE WITH THE SUBJECT CONTRACTOR 00014380
C   BIDDING AT M* AND M**.                                  00014390
C                                                            00014400
C                                                            00014410
C                                                            00014420
 2506 DO 1060 I=13,16                                        00014430
      DO 1061 J=1,6                                          00014440
      GDIST(I,J)=0.                                          00014450
 1061 CONTINUE                                               00014460
 1060 CONTINUE                                               00014470
      IF (CUW.EQ.0) GO TO 2507                               00014480
      GDIST(13,1)=CU1/FLOAT(CUW)                             00014490
      GDIST(14,1)=CW1/FLOAT(CUW)                             00014500
      GDIST(15,1)=CU2/FLOAT(CUW)                             00014510
      GDIST(16,1)=CW2/FLOAT(CUW)                             00014520
      REWIND 14                                              00014530
      DO 1062 M=1,CUW                                        00014540
      READ(14,1930) (DATA(I),I=13,16)                        00014550
      DO 1063 I=13,16                                        00014560
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      XMX(I)=DATA(I)-GDIST(I,1)                            00014570
      DO 1064 J=2,4                                        00014580
      GDIST(I,J)=GDIST(I,J)+XMX(I)**J                      00014590
 1064 CONTINUE                                             00014600
 1063 CONTINUE                                             00014610
 1062 CONTINUE                                             00014620
      DO 1065 I=13,16                                      00014630
      DO 1066 J=2,4                                        00014640
      GDIST(I,J)=GDIST(I,J)/FLOAT(CUW)                     00014650
 1066 CONTINUE                                             00014660
 1065 CONTINUE                                             00014670
      DO 1067 I=13,16                                      00014680
      IF (GDIST(I,2).EQ.0.) GO TO 1068                     00014690
      GDIST(I,5)=GDIST(I,3)/GDIST(I,2)**1.5                00014700
      GDIST(I,6)=GDIST(I,4)/GDIST(I,2)**2                  00014710
      GO TO 1067                                           00014720
 1068 GDIST(I,5)=0.                                        00014730
      GDIST(I,6)=0.                                        00014740
 1067 CONTINUE                                             00014750
C                                                          00014760
C                                                          00014770
C                                                          00014780
C  DETERMINE MOMENTS, SKEWNESS AND KURTOSIS FOR THE COMPETITOR'S    00014790
C  PERCEIVED ESTIMATED COSTS, BIDS, AND PERCEIVED GROSS PROFITS WITH 00014800
C  THE SUBJECT CONTRACTOR BIDDING AT M*.                  00014810
C                                                          00014820
C                                                          00014830
C                                                          00014840
 2507 DO 1070 I=17,19                                      00014850
      DO 1071 J=1,6                                        00014860
      GDIST(I,J)=0.                                        00014870
 1071 CONTINUE                                             00014880
 1070 CONTINUE                                             00014890
      IF (CCWONM.EQ.0) GO TO 2510                          00014900
      GDIST(17,1)=CCJBS1/FLOAT(CCWONM)                     00014910
      GDIST(18,1)=CCBID1/FLOAT(CCWONM)                     00014920
      GDIST(19,1)=CPGP1/FLOAT(CCWONM)                      00014930
      REWIND 10                                            00014940
      DO 1072 M=1,CCWONM                                   00014950
      READ(10,1910) (DATA(I),I=17,19)                      00014960
      DO 1073 I=17,19                                      00014970
      XMX(I)=DATA(I)-GDIST(I,1)                            00014980
      DO 1074 J=2,4                                        00014990
      GDIST(I,J)=GDIST(I,J)+XMX(I)**J                      00015000
 1074 CONTINUE                                             00015010
 1073 CONTINUE                                             00015020
 1072 CONTINUE                                             00015030
      DO 1075 I=17,19                                      00015040
      DO 1076 J=2,4                                        00015050
      GDIST(I,J)=GDIST(I,J)/FLOAT(CCWONM)                  00015060
 1076 CONTINUE                                             00015070
 1075 CONTINUE                                             00015080
      DO 1077 I=17,19                                      00015090
      IF (GDIST(I,2).EQ.0.) GO TO 1079                     00015100
      GDIST(I,5)=GDIST(I,3)/GDIST(I,2)**1.5                00015110
      GDIST(I,6)=GDIST(I,4)/GDIST(I,2)**2                  00015120
```

```
      GO TO 1077                                              00015130
 1079 GDIST(I,5)=0.                                           00015140
      GDIST(I,6)=0.                                           00015150
 1077 CONTINUE                                                00015160
C                                                             00015170
C                                                             00015180
C                                                             00015190
C  DETERMINE MOMENTS, SKEWNESS AND KURTOSIS FOR THE COMPETITOR'S 00015200
C  PERCEIVED ESTIMATED COSTS, BIDS, AND PERCEIVED GROSS PROFITS WITH 00015210
C  THE SUBJECT CONTRACTOR BIDDING AT M**.                    00015220
C                                                             00015230
C                                                             00015240
C                                                             00015250
 2510 DO 1080 I=20,22                                         00015260
      DO 1081 J=1,6                                           00015270
      GDIST(I,J)=0.                                           00015280
 1081 CONTINUE                                                00015290
 1080 CONTINUE                                                00015300
      IF (CCWNMM.EQ.0) GO TO 2512                             00015310
      GDIST(20,1)=CCJBS2/FLOAT(CCWNMM)                        00015320
      GDIST(21,1)=CCBID2/FLOAT(CCWNMM)                        00015330
      GDIST(22,1)=CPGP2/FLOAT(CCWNMM)                         00015340
      REWIND 11                                               00015350
      DO 1082 M=1,CCWNMM                                      00015360
      READ(11,1910) (DATA(I),I=20,22)                         00015370
      DO 1083 I=20,22                                         00015380
      XMX(I)=DATA(I)-GDIST(I,1)                               00015390
      DO 1084 J=2,4                                           00015400
      GDIST(I,J)=GDIST(I,J)+XMX(I)**J                         00015410
 1084 CONTINUE                                                00015420
 1083 CONTINUE                                                00015430
 1082 CONTINUE                                                00015440
      DO 1085 I=20,22                                         00015450
      DO 1086 J=2,4                                           00015460
      GDIST(I,J)=GDIST(I,J)/FLOAT(CCWNMM)                     00015470
 1086 CONTINUE                                                00015480
 1085 CONTINUE                                                00015490
      DO 1087 I=20,22                                         00015500
      IF (GDIST(I,2).EQ.0.) GO TO 1089                        00015510
      GDIST(I,5)=GDIST(I,3)/GDIST(I,2)**1.5                   00015520
      GDIST(I,6)=GDIST(I,4)/GDIST(I,2)**2                     00015530
      GO TO 1087                                              00015540
 1089 GDIST(I,5)=0.                                           00015550
      GDIST(I,6)=0.                                           00015560
 1087 CONTINUE                                                00015570
C                                                             00015580
C                                                             00015590
C                                                             00015600
C  DETERMINE NET PROFITS FOR THE SAMPLE                       00015610
C                                                             00015620
C                                                             00015630
C                                                             00015640
 2512 CNF1=CGP1-CTEC1-COHC1                                   00015650
      CNF2=CGP2-CTEC2-COHC2                                   00015660
C                                                             00015670
C                                                             00015680
```

```
C                                                                  00015690
C  PRINT VALUES THAT ARE LEFT IN ARRAYS PROF1 AND PROF2 WHEN THE SAMPLE 00015700
C  HAS ENDED IF A COMPLETE TABULATION OF RESULTS FOR SAMPLE SPECIFIED.  00015710
C  THESE PROJECTS ARE ONLY PARTIALLY COMPLETE AND DO NOT ENTER INTO ANY 00015720
C  ANALYSES.                                                        00015730
C                                                                  00015740
C                                                                  00015750
C                                                                  00015760
  730 IF (PRNOP1.EQ.2) GO TO 740                                   00015770
      GO TO 754                                                    00015780
  740 DO 1030 PN=1,200                                             00015790
      IF (PROF1(PN,1).EQ.0.) GO TO 750                             00015800
      WRITE(6,700) (PROF1(PN,I), I=1,8)                            00015810
  750 IF (PROF2(PN,1).EQ.0.) GO TO 1030                            00015820
      WRITE(6,710) (PROF2(PN,I), I=1,8)                            00015830
 1030 CONTINUE                                                     00015840
C                                                                  00015850
C                                                                  00015860
C                                                                  00015870
C  PRINT SUMMARY REPORT FOR EACH SAMPLE.                           00015880
C                                                                  00015890
C                                                                  00015900
C                                                                  00015910
  754 WRITE(6,756) NS                                              00015920
  756 FORMAT('1',//////,42X,49('*'),/,42X,'*',47X,'*',/,42X,'*',5X,'SUMMA00015930
     $RY OF RESULTS FOR SAMPLE NO.',I4,5X,'*',/,42X,'*',47X,'*',/, 00015940
     $42X,49('*'))                                                 00015950
C                                                                  00015960
      WRITE(6,760) KB,CB,WMAX,BONDCP,OPTJS                         00015970
  760 FORMAT(////,10X,'SAMPLE PARAMETERS:',/,10X,18('-'),///,16X,  00015980
     $'DECISION MAKING TIME INTERVAL (K):',9X,E10.4,/,16X,'PERCEIVED OPP00015990
     $ORTUNITY FOR ACHIEVEMENT (C):',1X,E10.4,/,16X,               00016000
     $'WORKING CAPITAL CONSTRAINT RATE (WMAX):',4X,E10.4,/,16X,    00016010
     $'BONDING CAPACITY:',26X,E10.4,/,16X,'CONSTANT ESTIMATED PROJECT SI00016020
     $ZE:',11X,E10.4)                                              00016030
      WRITE(6,820) A,B,MAXPRO,APRIME,BPRIME                        00016040
  820 FORMAT(16X,'LOW BACKLOG WITH OPS AT MAX EFFICIENCY:',4X,E10.4,/, 00016050
     $16X,'HIGH BACKLOG WITH OPS AT MAX EFFICIENCY:',3X,E10.4,/,   00016060
     $16X,'RANGE OF EFFICIENT OPERATIONS:',13X,E10.4,/,            00016070
     $16X,'LOW BACKLOG BEFORE M* IS MODIFIED:',9X,E10.4,/,         00016080
     $16X,'HIGH BACKLOG BEFORE M* IS MODIFIED:',8X,E10.4)          00016090
C                                                                  00016100
      WRITE(6,822) INJMON                                          00016110
  822 FORMAT(16X,'NUMBER OF PROJECTS BACKLOGGED IN START-UP:',1X,I3) 00016120
C                                                                  00016130
      WRITE(6,762) CNJOBS,TAMD1,GPP1,CNJOBS,TAMD2,GPP2             00016140
  762 FORMAT(////,10X,'ANALYSIS OF MARKET:',/,10X,19('-'),///,16X, 00016150
     $'NUMBER OF BID',2X,'SUBJECT CONTRACTOR',3X,'TOTAL AWARDED',2X, 00016160
     $'TOTAL POTENTIAL',/,16X,'OPPORTUNITIES',4X,'BIDDING POLICY',4X, 00016170
     $'MARKET DOLLARS',3X,'GROSS PROFITS',///,20X,I5,14X,'M*',12X,E10.4, 00016180
     $6X,E10.4,/,20X,I5,14X,'M**',11X,E10.4,6X,E10.4)              00016190
C                                                                  00016200
      IF (PRNOP1.EQ.1) GO TO 2210                                  00016210
C                                                                  00016220
      WRITE(6,764)                                                 00016230
  764 FORMAT(///,16X,'GENERATED DISTRIBUTION OF ESTIMATED JOB SIZE:') 00016240
```

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```
C                                                                    00016250
      WRITE(6,766)                                                    00016260
  766 FORMAT(////,47X,'THIRD',5X,'FOURTH',/,25X,'MEAN',5X,'VARIANCE',4X, 00016270
     $'MOMENT',5X,'MOMENT',4X,'SKEWNESS',3X,'KURTOSIS')               00016280
      WRITE(6,768) (GDIST(2,I),I=1,6)                                 00016290
  768 FORMAT(/,22X,E10.4,5(1X,E10.4))                                 00016300
C                                                                    00016310
      WRITE(6,770)                                                    00016320
  770 FORMAT(////,16X,'GENERATED DISTRIBUTION OF MONTHLY ARRIVAL RATE OF 00016330
     $BID OPPORTUNITIES:')                                            00016340
      WRITE(6,766)                                                    00016350
      WRITE(6,768) (GDIST(1,I),I=1,6)                                 00016360
C                                                                    00016370
 2210 WRITE(6,772)                                                    00016380
  772 FORMAT(////,10X,'ANALYSIS OF SUBJECT CONTRACTOR PERFORMANCE:',/, 00016390
     $10X,43('-'),///,16X,'BIDDING',1X,'#PROJECT',1X,'#PROJECT',2X,  00016400
     $'ESTIMATED',3X,'GROSS',6X,'ACTUAL',5X,'GROSS',4X,'ESTIMATING',2X, 00016410
     $'OVERHEAD',5X,'NET',/,17X,'POLICY',3X,'BID',6X,'WON',7X,'COSTS', 00016420
     $5X,'SALES',6X,'COSTS',5X,'PROFITS',5X,'COSTS',6X,'COSTS',5X,    00016430
     $'PROFITS')                                                      00016440
C                                                                    00016450
      WRITE(6,774) CBIDM,CWONM,CJS1,CBID1,CACCT1,CGP1,CTEC1,COHC1,CNP1, 00016460
     $CBIDMM,CWONMM,CJS2,CBID2,CACCT2,CGP2,CTEC2,COHC2,CNP2           00016470
  774 FORMAT(/,18X,'M*',5X,I5,4X,I5,3X,E10.4,6(1X,E10.4),/,18X,'M**', 00016480
     $4X,I5,4X,I5,3X,E10.4,6(1X,E10.4))                               00016490
C                                                                    00016500
      IF (PRNOP1.EQ.1) GO TO 2212                                     00016510
C                                                                    00016520
      WRITE(6,776)                                                    00016530
  776 FORMAT(////,16X,'DISTRIBUTION OF BACKLOG OF WORK (END OF EACH MONTH 00016540
     $):')                                                            00016550
      WRITE(6,778)                                                    00016560
  778 FORMAT(////,22X,'BIDDING',26X,'THIRD',5X,'FOURTH',/,23X,'POLICY', 00016570
     $4X,'MEAN',5X,'VARIANCE',4X,'MOMENT',5X,'MOMENT',4X,'SKEWNESS',3X, 00016580
     $'KURTOSIS')                                                     00016590
      WRITE(6,780) (GDIST(13,I),I=1,6),(GDIST(15,J),J=1,6)            00016600
  780 FORMAT(/,24X,'M*',4X,E10.4,5(1X,E10.4),/,24X,'M**',3X,E10.4,    00016610
     $5(1X,E10.4))                                                    00016620
C                                                                    00016630
      WRITE(6,782)                                                    00016640
  782 FORMAT(////,16X,'DISTRIBUTION OF WORK COMPLETE RATE (BEGINNING OF E 00016650
     $ACH MONTH):')                                                   00016660
      WRITE(6,778)                                                    00016670
      WRITE(6,780) (GDIST(14,I),I=1,6),(GDIST(16,J),J=1,6)            00016680
C                                                                    00016690
      WRITE(6,784)                                                    00016700
  784 FORMAT(////,16X,'DISTRIBUTION OF ESTIMATED COSTS:')             00016710
      WRITE(6,778)                                                    00016720
      WRITE(6,780) (GDIST(3,I),I=1,6),(GDIST(8,J),J=1,6)              00016730
C                                                                    00016740
      WRITE(6,786)                                                    00016750
  786 FORMAT(////,16X,'DISTRIBUTION OF BIDS:')                        00016760
      WRITE(6,778)                                                    00016770
      WRITE(6,780) (GDIST(4,I),I=1,6),(GDIST(9,J),J=1,6)              00016780
C                                                                    00016790
      WRITE(6,788)                                                    00016800
```

```
  788 FORMAT(////,16X,'DISTRIBUTION OF ACTUAL COSTS:')              00016810
      WRITE(6,778)                                                   00016820
      WRITE(6,780) (GDIST(5,I),I=1,6),(GDIST(10,J),J=1,6)            00016830
    C                                                                 00016840
      WRITE(6,790)                                                   00016850
  790 FORMAT(////,16X,'DISTRIBUTION OF GROSS PROFITS:')              00016860
      WRITE(6,778) .                                                 00016870
      WRITE(6,780) (GDIST(6,I),I=1,6),(GDIST(11,J),J=1,6)            00016880
    C                                                                 00016890
      WRITE(6,792)                                                   00016900
  792 FORMAT(////,16X,'DISTRIBUTION OF NET PROFITS:')                00016910
      WRITE(6,778)                                                   00016920
      WRITE(6,780) (GDIST(7,I),I=1,6),(GDIST(12,J),J=1,6)            00016930
    C                                                                 00016940
 2212 WRITE(6,794) CNJOBS,CCWONM,CCJBS1,CCBID1,CPGP1,CNJOBS,CCWNMM,   00016950
     $CCJBS2,CCBID2,CPGP2                                            00016960
  794 FORMAT(////,10X,'ANALYSIS OF COMPETITOR PERCEIVED PERFORMANCE:',/, 00016970
     $10X,45('-'),////,16X,'SUBJECT',1X,'#PROJECT',1X,'#PROJECT',1X,  00016980
     $'PERCEIVED',13X,'PERCEIVED',/,18X,'BID',5X,'BID',6X,'WON',6X,   00016990
     $'COSTS',5X,'SALES',5X,'G PROFITS',//,18X,'M*',6X,I5,4X,I5,      00017000
     $3(1X,E10.4),/,18X,'M**',5X,I5,4X,I5,3(1X,E10.4))               00017010
    C                                                                 00017020
      IF (PRNOP1.EQ.1) GO TO 2214                                    00017030
    C                                                                 00017040
      WRITE(6,796)                                                   00017050
  796 FORMAT(////,16X,'DISTRIBUTION OF PERCEIVED COSTS:')            00017060
      WRITE(6,778)                                                   00017070
      WRITE(6,780) (GDIST(17,I),I=1,6),(GDIST(20,J),J=1,6)           00017080
    C                                                                 00017090
      WRITE(6,798)                                                   00017100
  798 FORMAT(////,16X,'DISTRIBUTION OF BIDS:')                       00017110
      WRITE(6,778)                                                   00017120
      WRITE(6,780) (GDIST(18,I),I=1,6),(GDIST(21,J),J=1,6)           00017130
    C                                                                 00017140
      WRITE(6,800)                                                   00017150
  800 FORMAT(////,16X,'DISTRIBUTION OF PERCEIVED GROSS PROFITS:')    00017160
      WRITE(6,778)                                                   00017170
      WRITE(6,780) (GDIST(19,I),I=1,6),(GDIST(22,J),J=1,6)           00017180
    C                                                                 00017190
   .C                                                                 00017200
    C                                                                 00017210
    C   PUNCH SUMMARY REPORT FOR EACH SAMPLE.                         00017220
    C                                                                 00017230
    C                                                                 00017240
    C                                                                 00017250
 2214 IF (PRNOP1.EQ.2.OR.PRNOP1.EQ.3) GO TO 1004                     00017260
      IF (PRNOP2.NE.1) GO TO 1004                                    00017270
      WRITE(7,960) NS,KB,CB,WMAX,BONDCP,OPTJS                        00017280
  960 FORMAT(I4,6X,5E10.4)                                           00017290
      WRITE(7,962) CNJOBS,TAMD1,GPP1,TAMD2,GFP2                      00017300
  962 FORMAT(I5,5X,4E10.4)                                           00017310
      WRITE(7,964) CBIDM,CWONM,CJS1,CBID1,CAC1,CGP1,CTEC1,CNP1       00017320
  964 FORMAT(2I5,6E10.4)                                             00017330
      WRITE(7,964) CBIDMM,CWONMM,CJS2,CBID2,CAC2,CGP2,CTEC2,CNP2     00017340
      WRITE(7,966) CCWONM,CCJBS1,CCBID1,CPGP1                        00017350
  966 FORMAT(I5,5X,3E10.4)                                           00017360
```

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```
      WRITE(7,966) CCWNMM,CCJBS2,CCBID2,CPGP2                    00017370
      DO 1090 I=1,22                                             00017380
      WRITE(7,968) (GDIST(I,J),J=1,6)                            00017390
  968 FORMAT(6E10.4)                                             00017400
 1090 CONTINUE                                                   00017410
C                                                                00017420
C                                                                00017430
C                                                                00017440
 1004 CONTINUE                                                   00017450
 1999 CONTINUE                                                   00017460
 2000 STOP                                                       00017470
      END                                                        00017480
C                                                                00017490
C                                                                00017500
C                                                                00017510
C   SUBROUTINE FIND DETERMINES LAMBDA PARAMETERS.                00017520
C                                                                00017530
C                                                                00017540
C                                                                00017550
      SUBROUTINE FIND(A3,A4,I,IER,NIE)                           00017560
      REAL LAM                                                   00017570
      COMMON /LAMBDA/ LAM(6,4)                                   00017580
      IF (A3.EQ.0.AND.A4.EQ.0.) GO TO 40                         00017590
      IER=0                                                      00017600
      NIE=0                                                      00017610
      A=ABS(A3)                                                  00017620
      C=0.025                                                    00017630
      IF (A.LE.1.) GO TO 10                                      00017640
      C=0.05                                                     00017650
   10 REWIND 1                                                   00017660
   20 READ(1,21,END=30) AL3,AL4,(LAM(I,J),J=1,4)                 00017670
   21 FORMAT(6F10.2)                                             00017680
      R3=ABS(A-AL3)                                              00017690
      IF (R3.GT.C) GO TO 20                                      00017700
      R4=ABS(A4-AL4)                                             00017710
      IF (R4.GT.0.1) GO TO 20                                    00017720
      IF (A3.GE.0.) RETURN                                       00017730
      A=LAM(I,3)                                                 00017740
      LAM(I,3)=LAM(I,4)                                          00017750
      LAM(I,4)=ABS(A)                                            00017760
      LAM(I,1)=-LAM(I,1)                                         00017770
      RETURN                                                     00017780
   30 IER=1                                                      00017790
      RETURN                                                     00017800
   40 NIE=1                                                      00017810
      RETURN                                                     00017820
      END                                                        00017830
C                                                                00017840
C                                                                00017850
C                                                                00017860
C   FUNCTION DRAND1 GENERATES STANDARDIZED RANDOM PROBABILITIES. 00017870
C                                                                00017880
C                                                                00017890
C                                                                00017900
      FUNCTION DRAND1(LD)                                        00017910
      DATA KD/13917/                                            00017920
```

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```
          LD=LD*KD                                                00017930
          IF (LD.GT.0) GO TO 1                                     00017940
          LD=LD+2147483647+1                                       00017950
        1 DRAND1=LD                                                00017960
          DRAND1=DRAND1*.4656613E-9                                00017970
          RETURN                                                   00017980
          END                                                      00017990
C                                                                  00018000
C                                                                  00018010
C                                                                  00018020
C FUNCTION DRAND2 GENERATES STANDARDIZED RANDOM PROBABILITIES.     00018030
C                                                                  00018040
C                                                                  00018050
C                                                                  00018060
          FUNCTION DRAND2(LD)                                      00018070
          DATA KD/16807/                                           00018080
          LD=LD*KD                                                 00018090
          IF (LD.GT.0) GO TO 1                                     00018100
          LD=LD+2147483647+1                                       00018110
        1 DRAND2=LD                                                00018120
          DRAND2=DRAND2*.4656613E-9                                00018130
          RETURN                                                   00018140
          END                                                      00018150
C                                                                  00018160
C                                                                  00018170
C                                                                  00018180
C FUNCTION ROFP USES THE RS DISTRIBUTION TO DETERMINE VALUES OF THE RV.00018190
C                                                                  00018200
C                                                                  00018210
C                                                                  00018220
          FUNCTION ROFP(M1,M2,LAM1,LAM2,LAM3,LAM4,P)               00018230
          REAL M1,M2,LAM1,LAM2,LAM3,LAM4,P                         00018240
          IF (LAM2.EQ.0.) GO TO 10                                 00018250
          ROFP=M1+SQRT(M2)*(LAM1+(P**LAM3-(1.-P)**LAM4)/LAM2)      00018260
          RETURN                                                   00018270
       10 ROFP=0.                                                  00018280
          RETURN                                                   00018290
          END                                                      00018300
```

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APPENDIX D

BACKLOG FLOWCHART

Figure D.1 presents a detailed flowchart for the BACKLOG computer program. Each box in the flowchart represents a set of instructions or operations that is described by the enclosed title. The box titles in the flowchart correspond closely to the comments in the program listing presented in Appendix C. The box shapes correspond to the shapes used in the FLOWCHART computer program (a canned program available through the Instruction and Research Computer Center, The Ohio State University). Boxes for optional printing and executing statements are not included in the flowchart to prevent clutter such that a better understanding of the program may be obtained by the reader.

```
                    ┌─────────────┐
                    │    START    │
                    └──────┬──────┘
                           │
                           ▼
            ┌──────────────────────────────┐
            │  Declaration of Variables    │
            └──────────────┬───────────────┘
                           │
                           ▼
            ┌──────────────────────────────┐
            │  Read user specified         │
            │  information                 │
            └──────────────┬───────────────┘
                           │
                           ▼
            ┌──────────────────────────────┐
            │  Print summary of user       │
            │  specified information       │
            └──────────────┬───────────────┘
                           │
                           ▼
            ┌──────────────────────────────┐
            │  Determine lambda parameters for │
            │  random variable distributions   │
            └──────────────┬───────────────┘
                           │
        ┌───┐              ▼
        │ A │────────▶┌──────────────────────┐
        └───┘         │   Do loop for        │
                      │ number of experiments │
                      └──────────┬───────────┘
                                 │
                                 ▼
            ┌──────────────────────────────┐
            │ Determine points on W versus U │
            │ curve where M* will be modified │
            └──────────────┬───────────────┘
                           │
        ┌───┐              ▼
        │ B │────────▶┌──────────────────────┐
        └───┘         │   Do loop for        │
                      │ number of samples    │
                      └──────────┬───────────┘
                                 │
                                 ▼
            ┌──────────────────────────────┐
            │  Read sample parameters      │
            └──────────────┬───────────────┘
                           │
                           ▼
            ┌──────────────────────────────┐
            │  Clear arrays PROF1 and PROF2 │
            └──────────────┬───────────────┘
                           │
                           ▼
            ┌──────────────────────────────┐
            │ Initialize pointers for disk storage │
            └──────────────┬───────────────┘
                           │
                           ▼
            ┌──────────────────────────────┐
            │ Initialize backlog and bonding capacity │
            └──────────────┬───────────────┘
                           │
                           ▼
                        ┌─────┐
                        │  C  │
                        └─────┘
```

FIGURE D.1 -- FLOWCHART OF THE BACKLOG PROGRAM
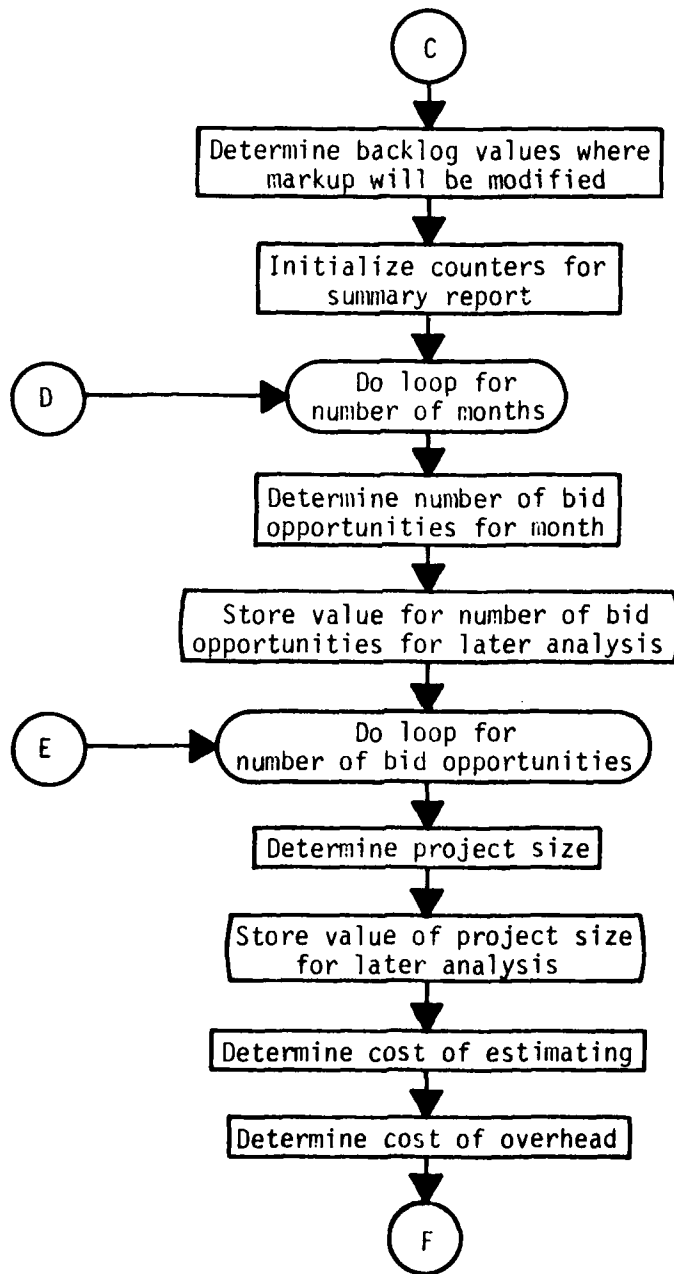
FIGURE D.1 -- FLOWCHART FOR THE BACKLOG PROGRAM (Continued)
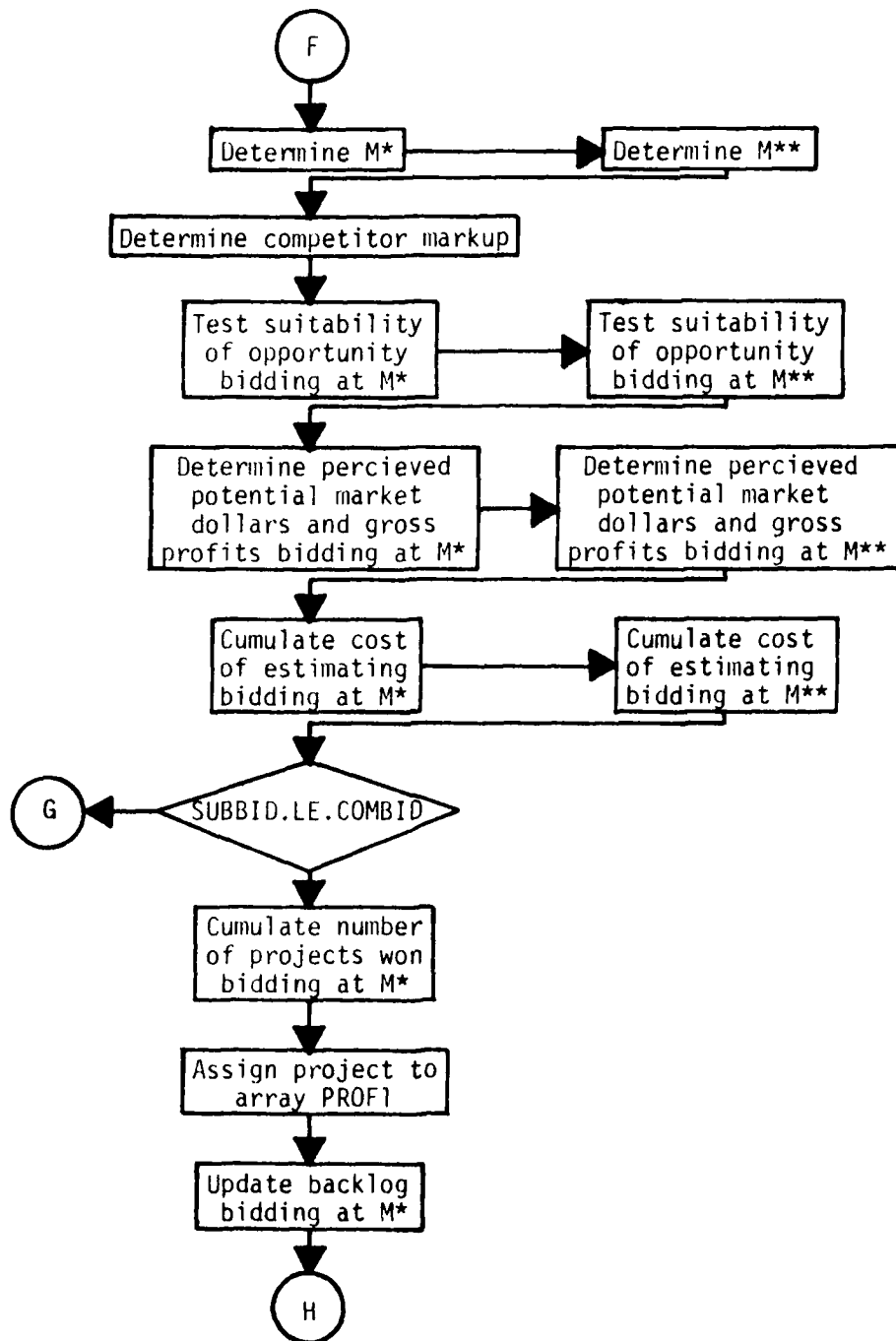
FIGURE D. 1 -- FLOWCHART FOR THE BACKLOG PROGRAM (Continued)
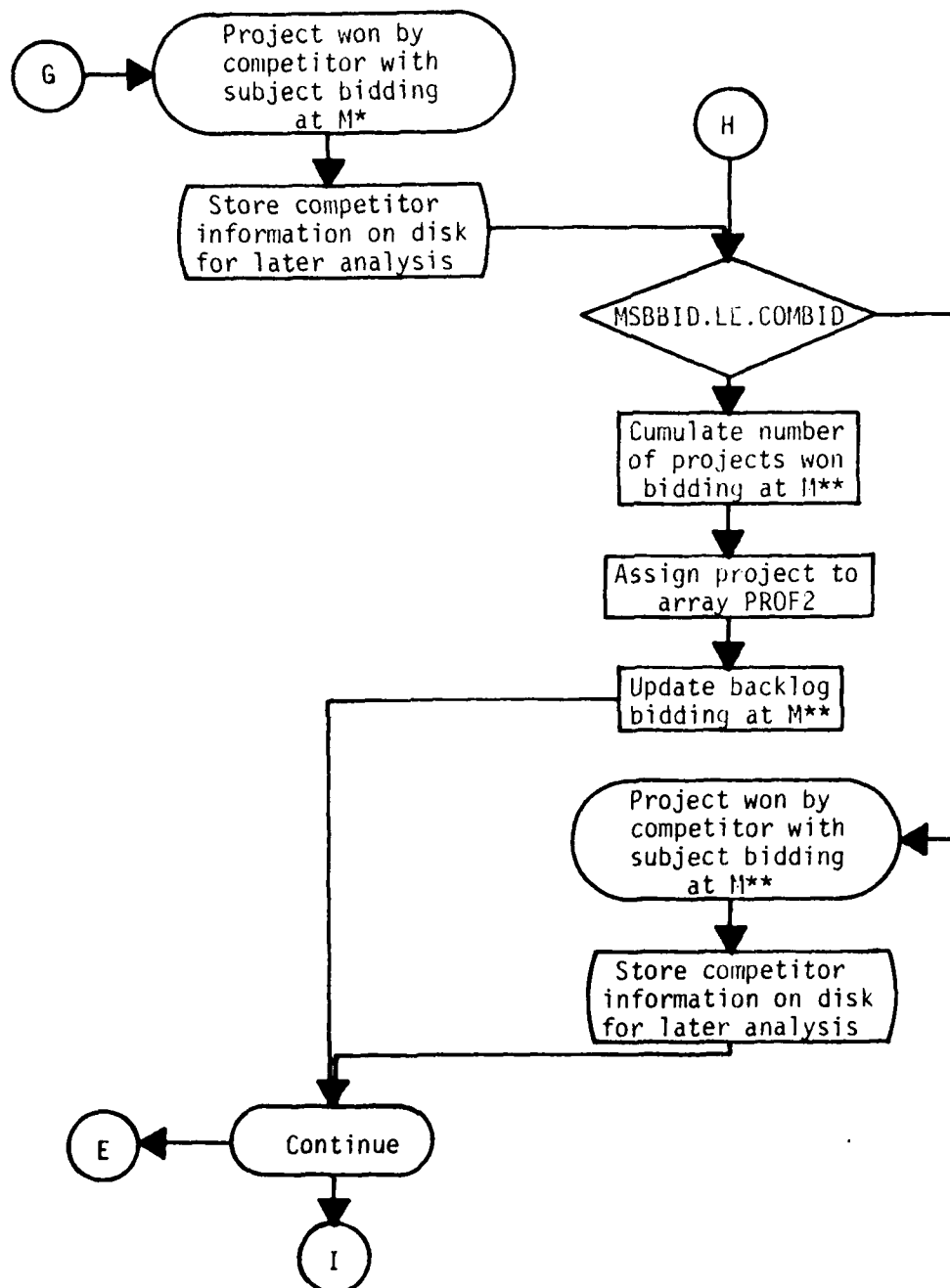
FIGURE D.1 -- FLOWCHART FOR THE BACKLOG PROGRAM (Continued)
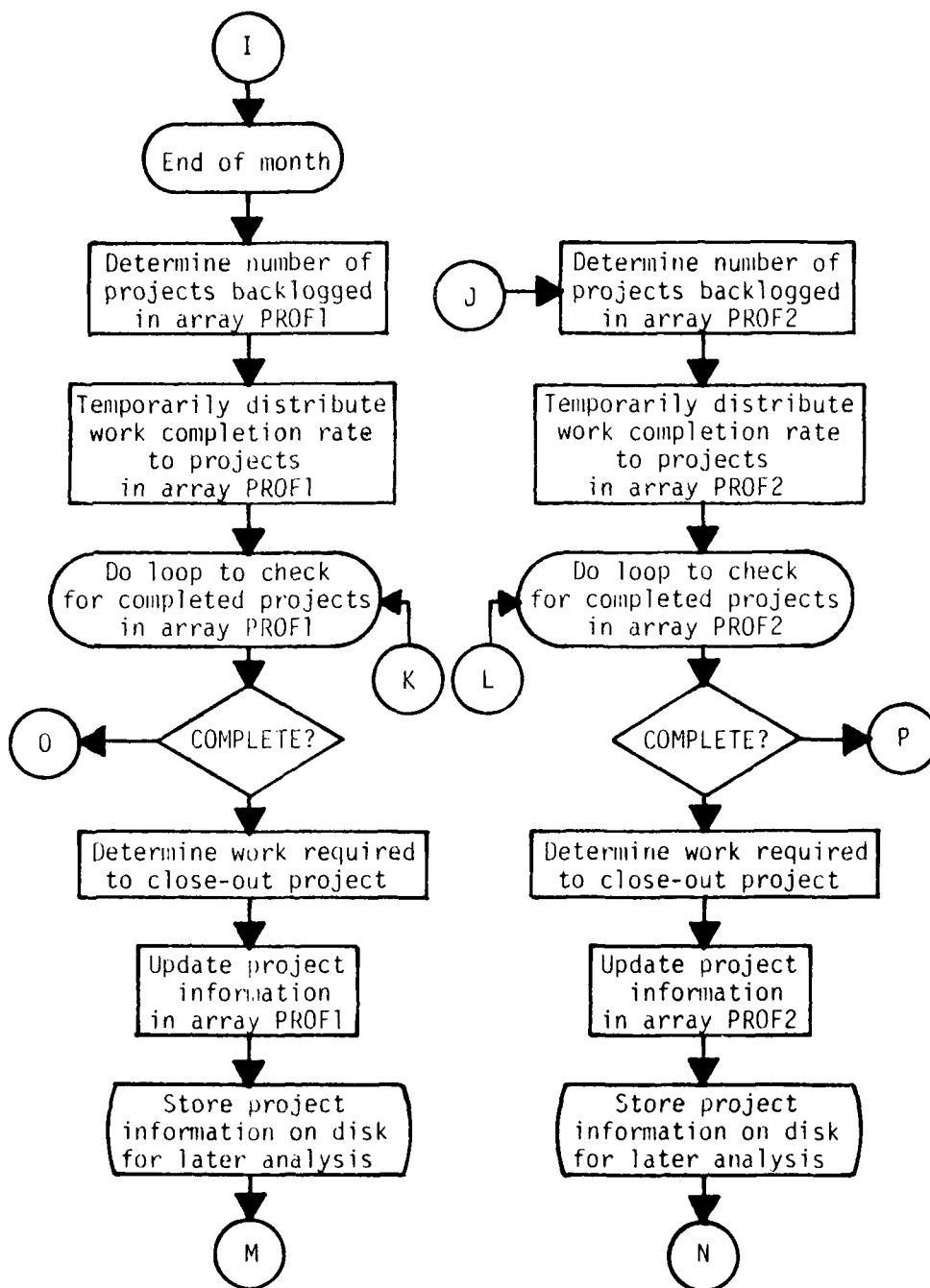
FIGURE D.1 -- FLOWCHART FOR THE BACKLOG PROGRAM (Continued)
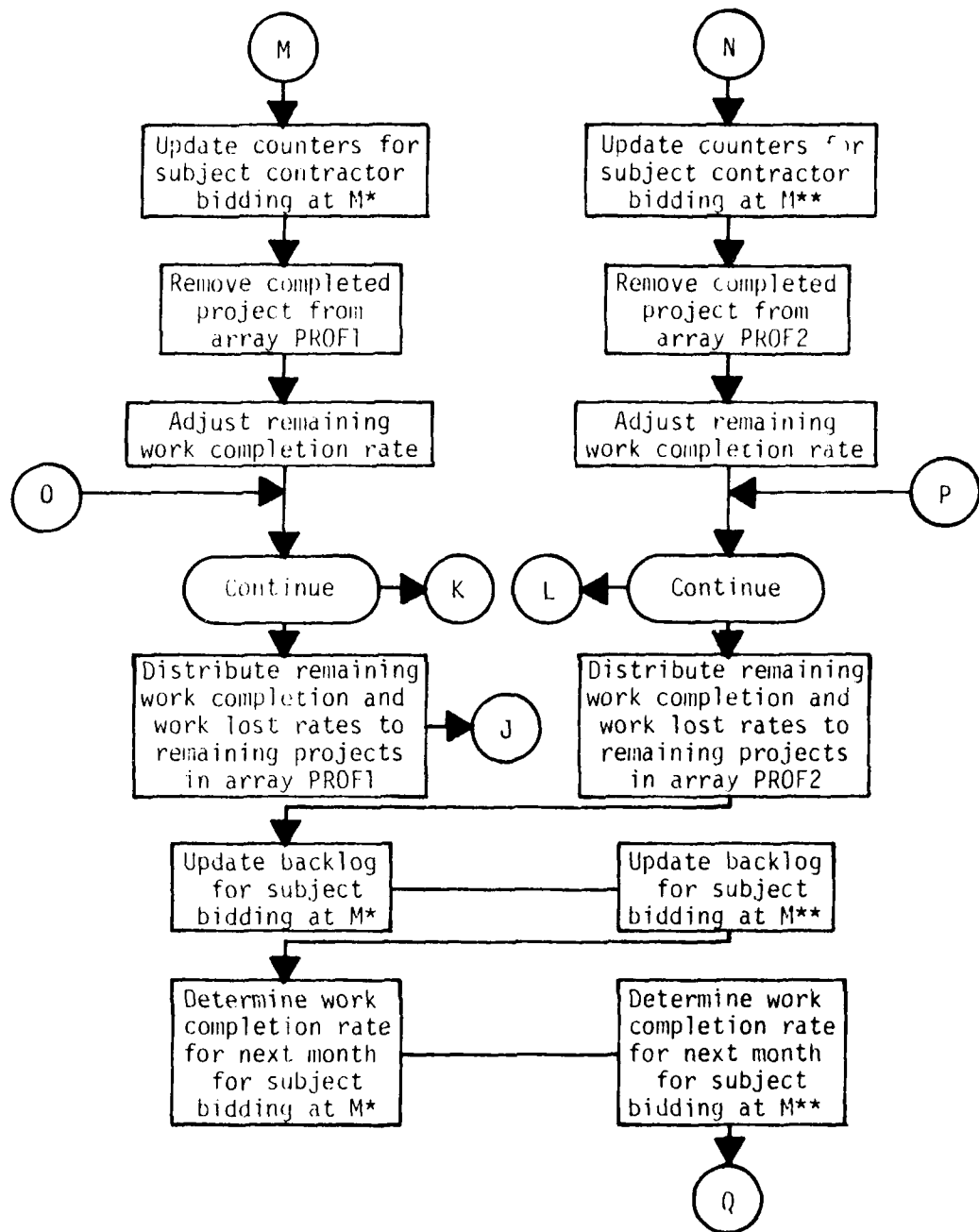
FIGURE D.1 -- FLOWCHART FOR THE BACKLOG PROGRAM (Continued)
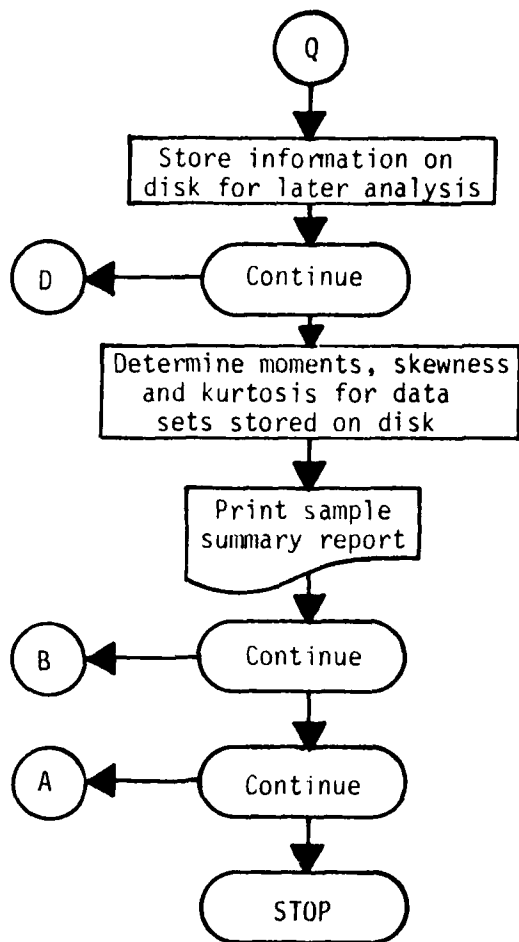
FIGURE D.1 -- FLOWCHART FOR THE BACKLOG PROGRAM (Continued)

APPENDIX E

BACKLOG CURVES

This appendix contains fitted and prediction backlog of work curves for various K and C combinations.
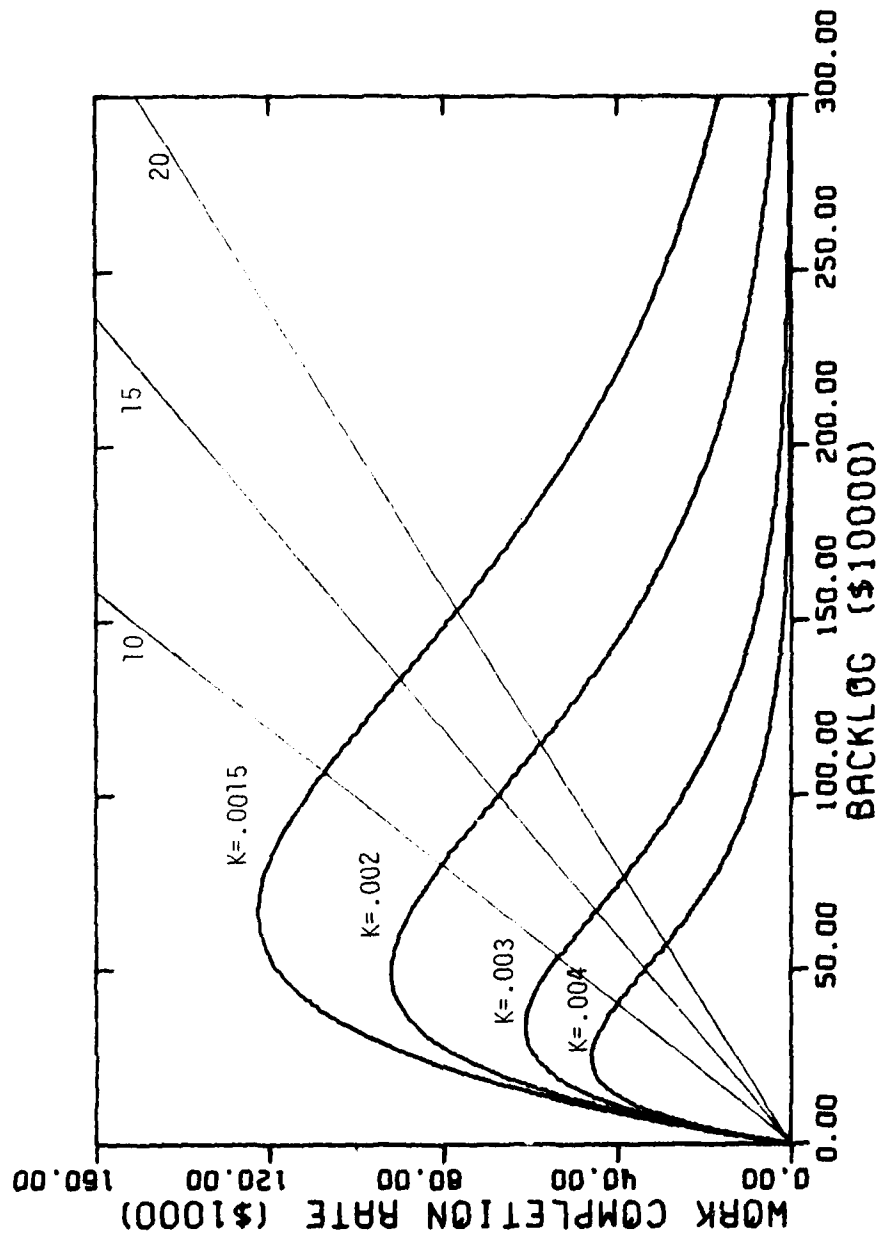
FIGURE E.1 -- FITTED BACKLOG CURVES, C=.5

211
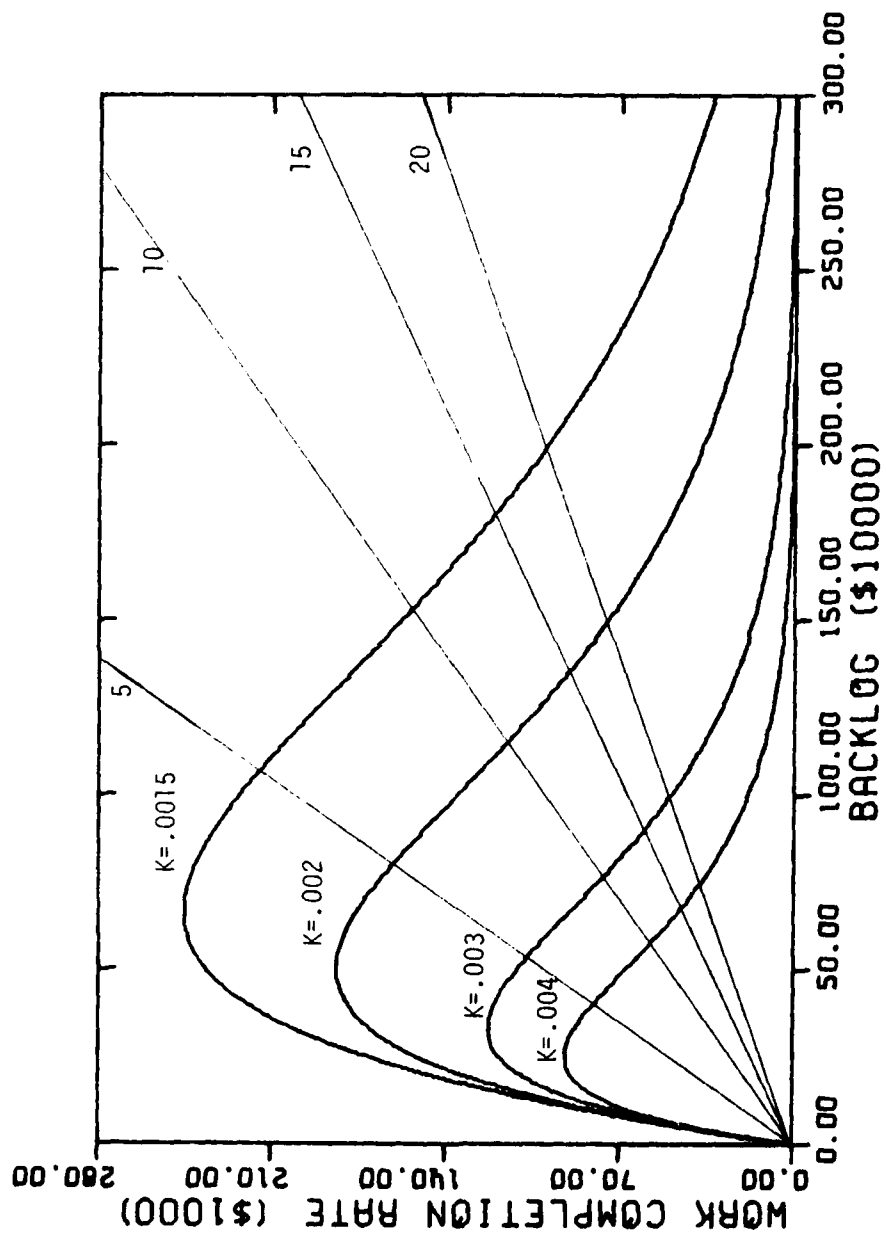
FIGURE E.2 -- FITTED BACKLOG CURVES, C=1.0

212
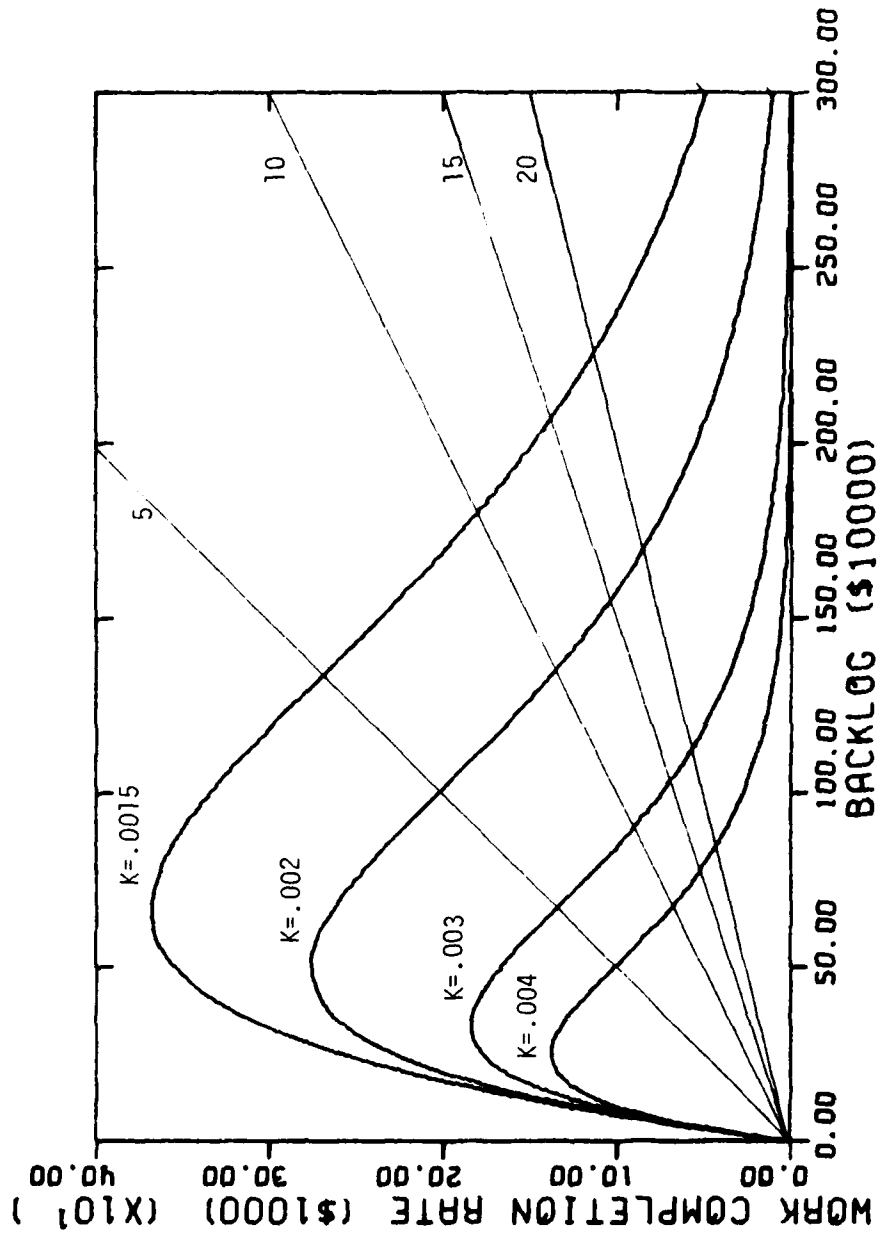
FIGURE E.3 -- FITTED BACKLOG CURVES, C=1.5

213
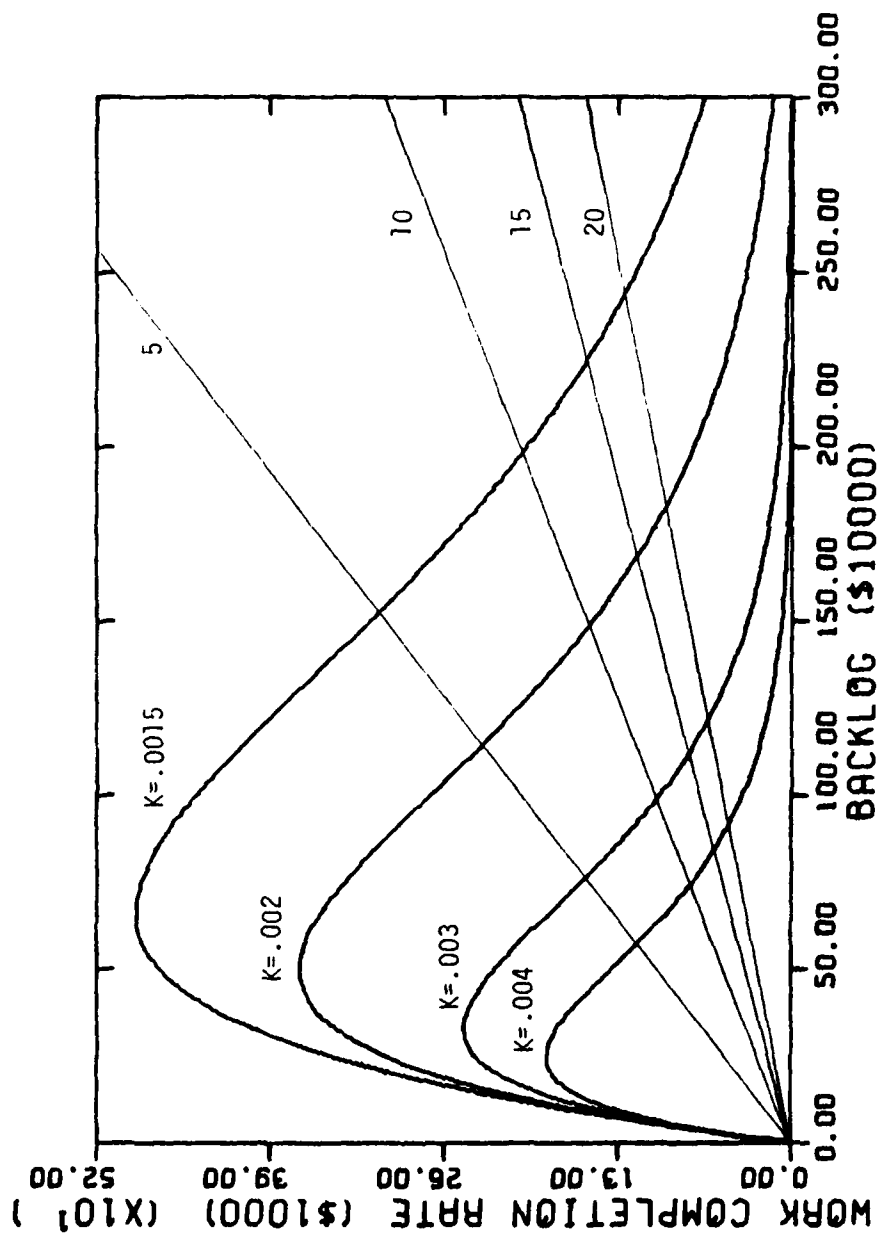
FIGURE E.4 -- FITTED BACKLOG CURVES, C=2.0

214
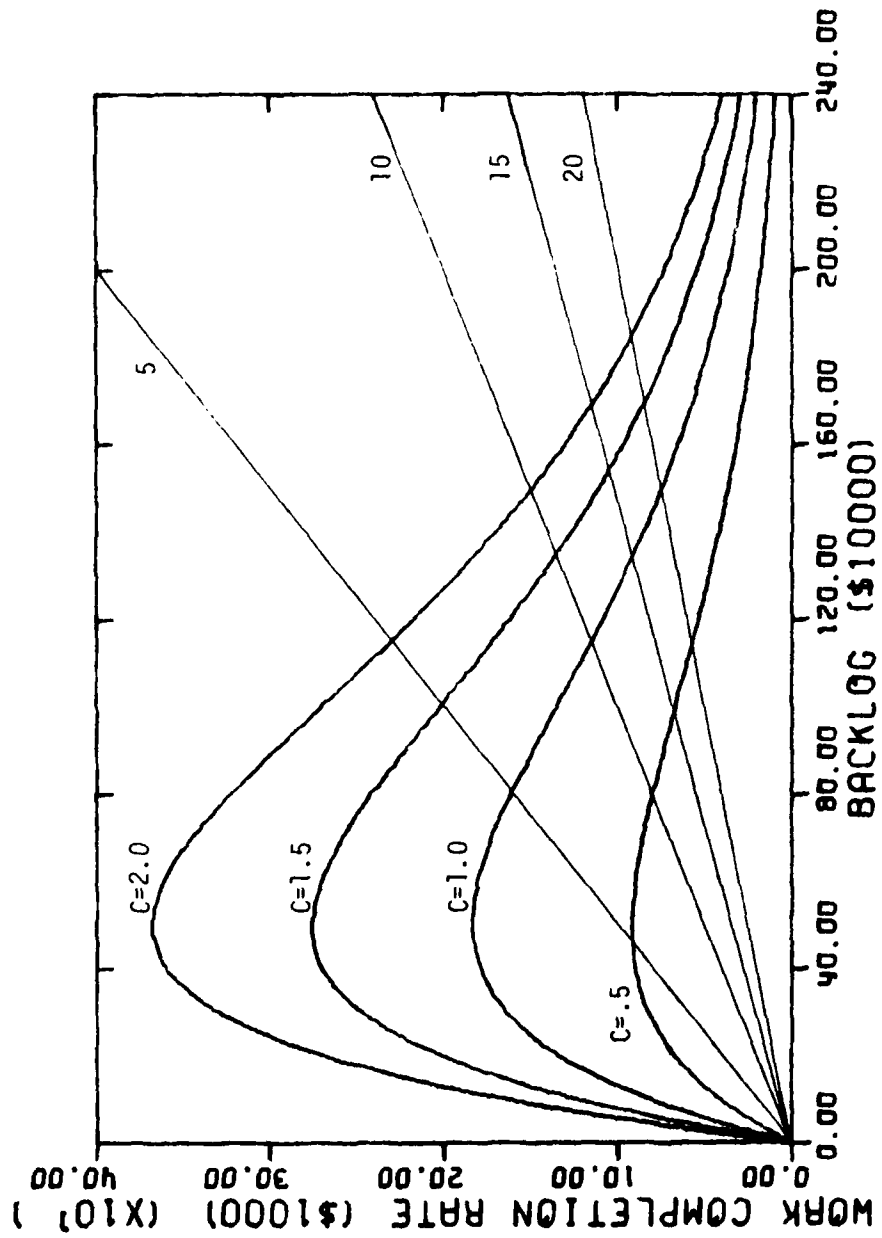
FIGURE E.5 -- FITTED BACKLOG CURVES, K=.002

215
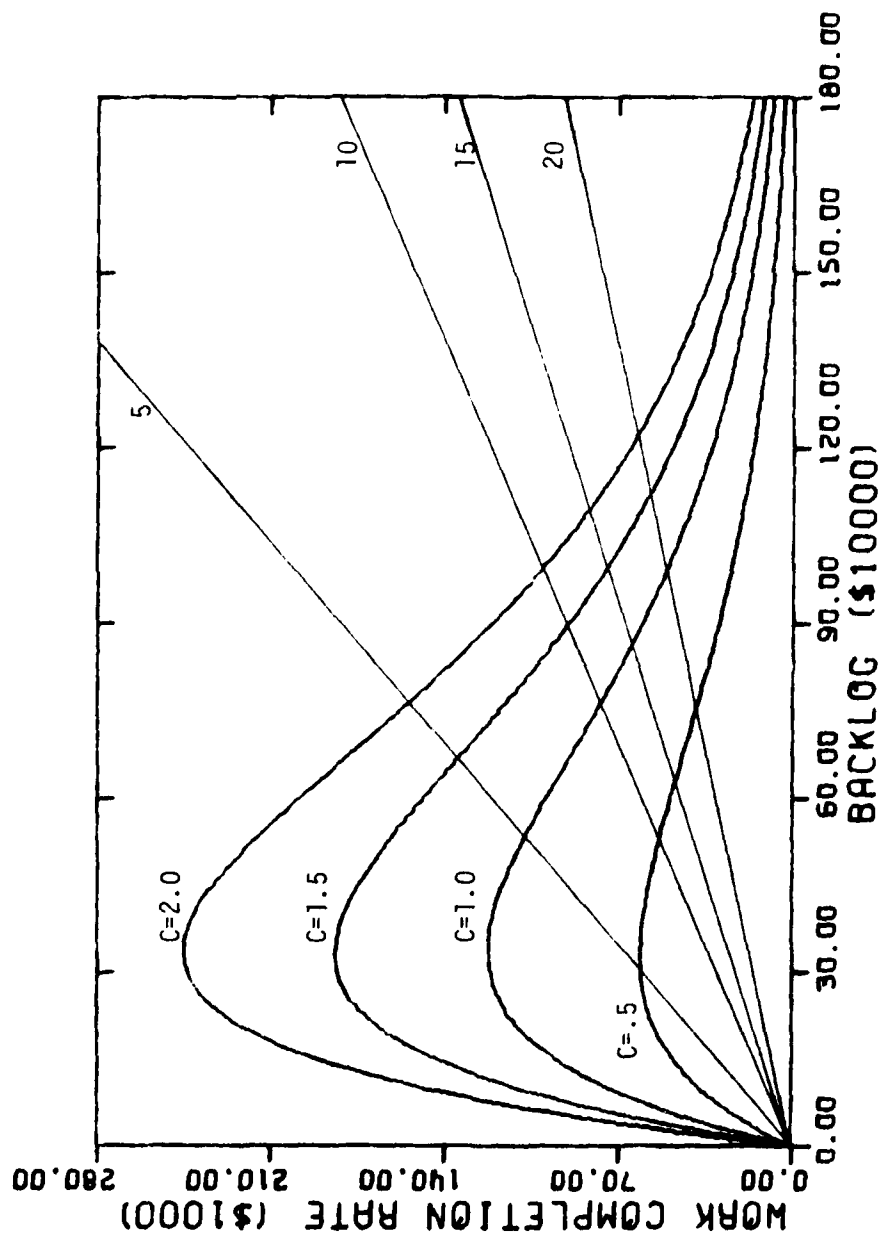
FIGURE E.6 -- FITTED BACKLOG CURVES, K=.003

216
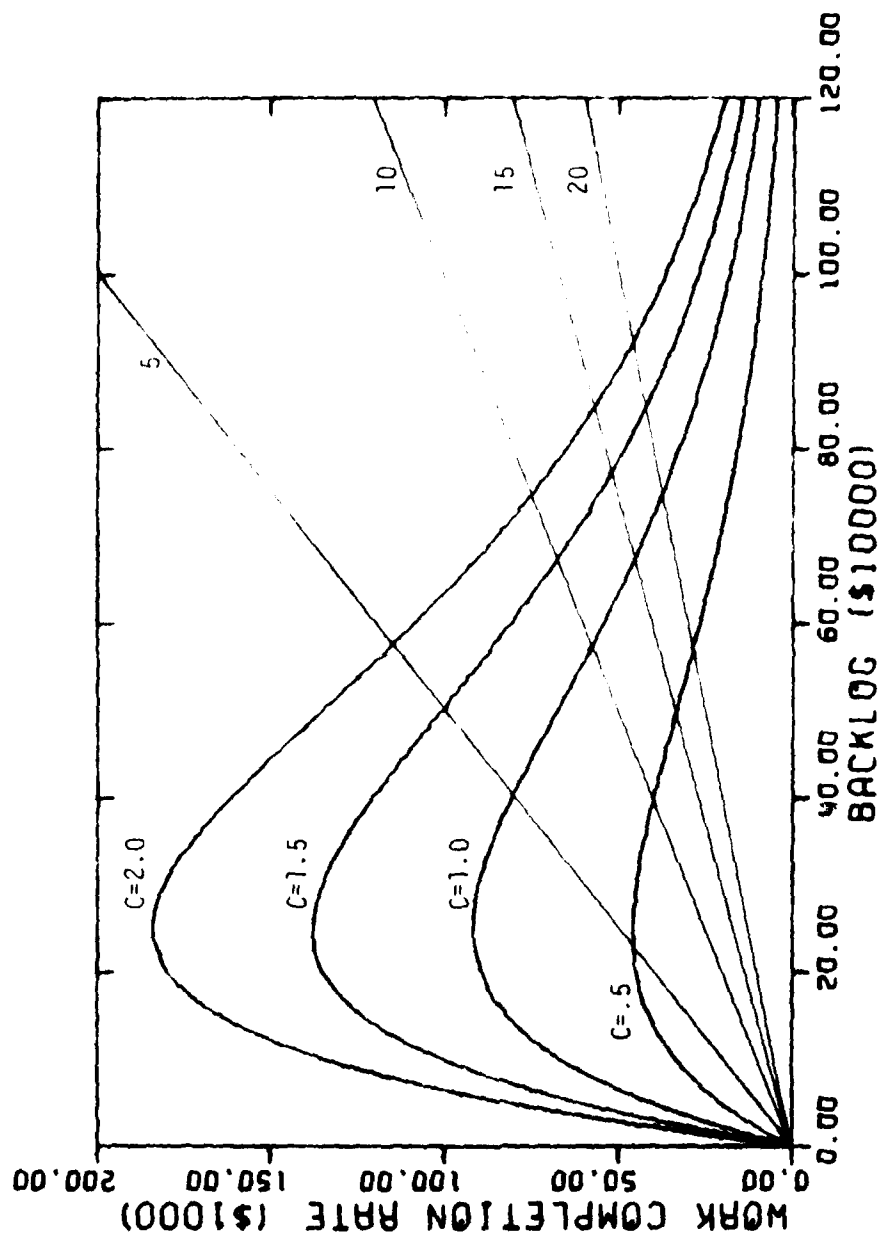
FIGURE E.7 -- FITTED BACKLOG CURVES, K=.004

217
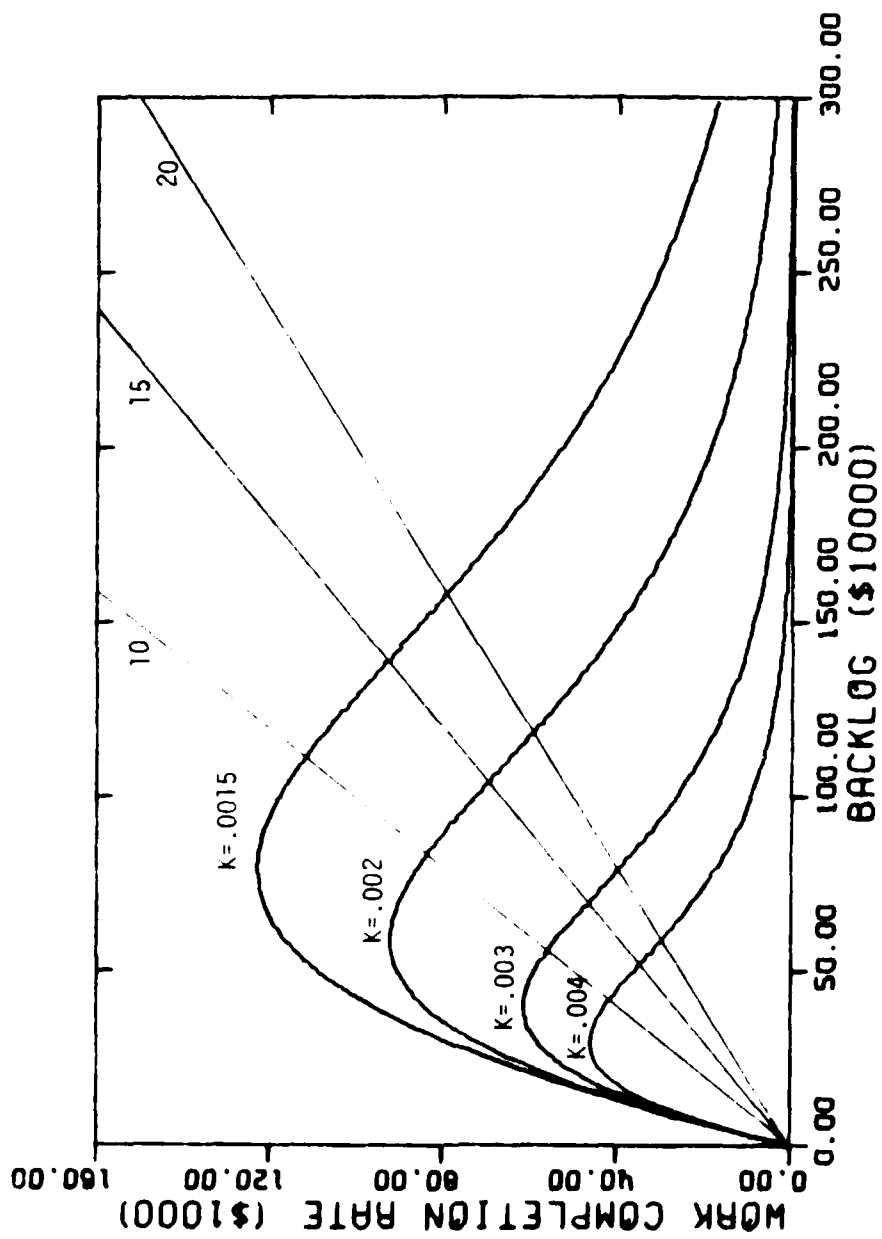
FIGURE E.8 -- PREDICTION BACKLOG CURVES, C=.5

218
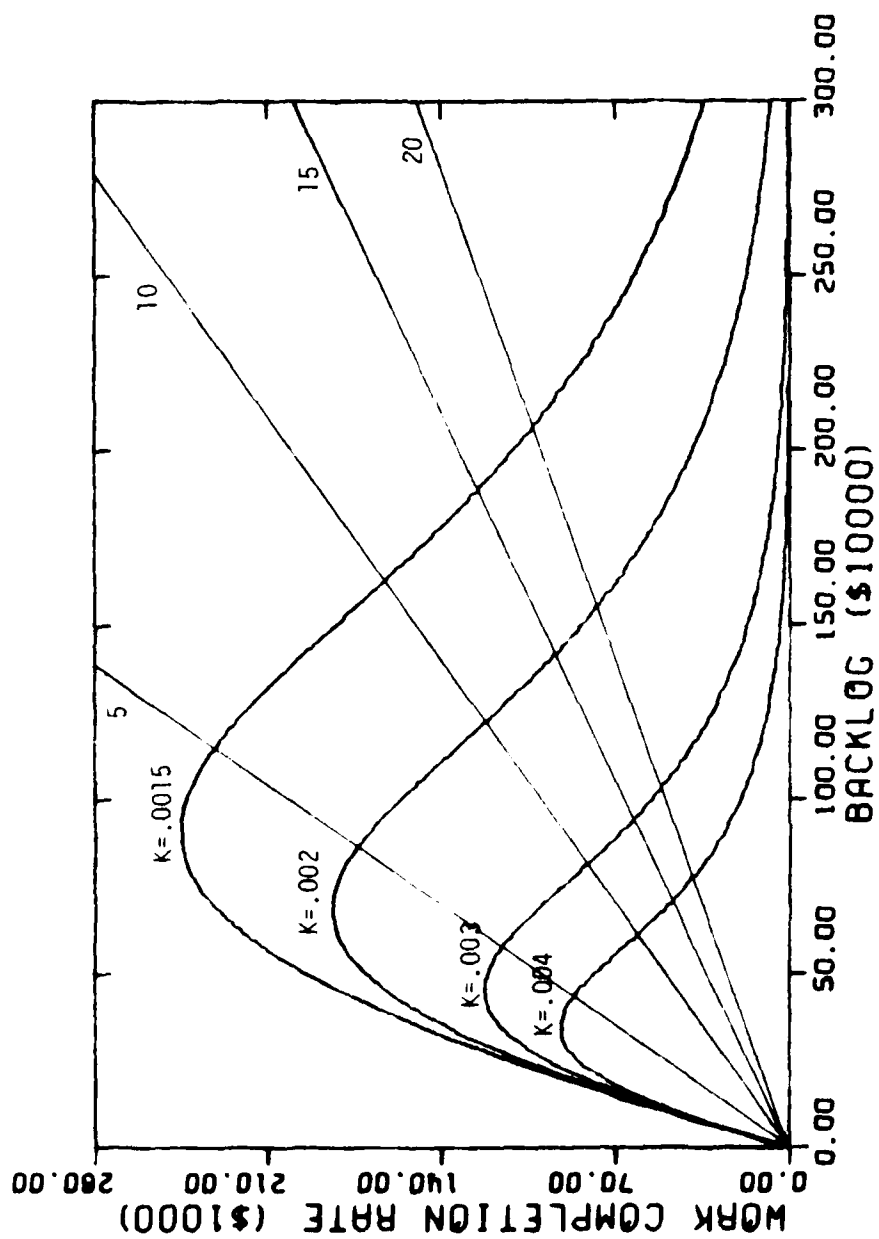
FIGURE E.9 -- PREDICTION BACKLOG CURVES, C=1.0
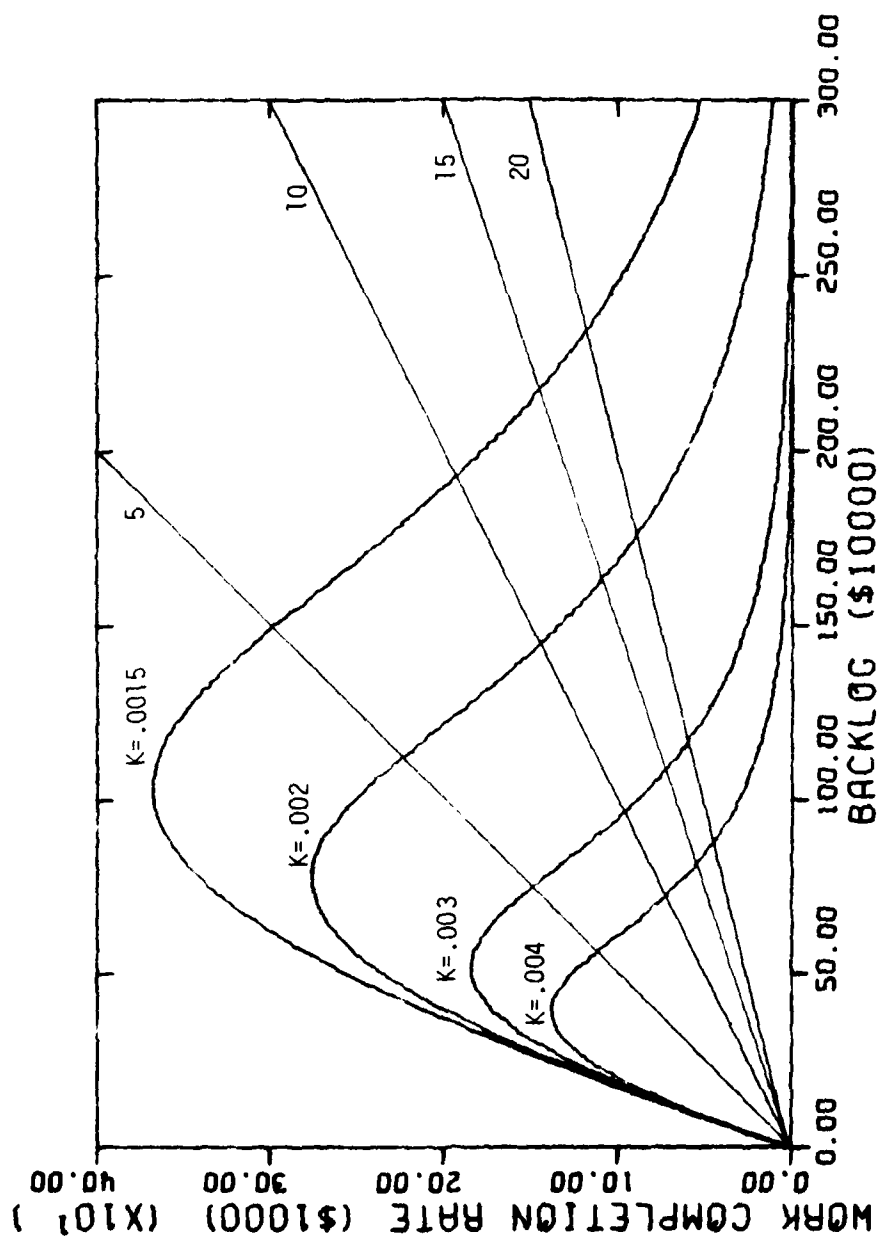
FIGURE E.10 -- PREDICTION BACKLOG CURVES, C=1.5
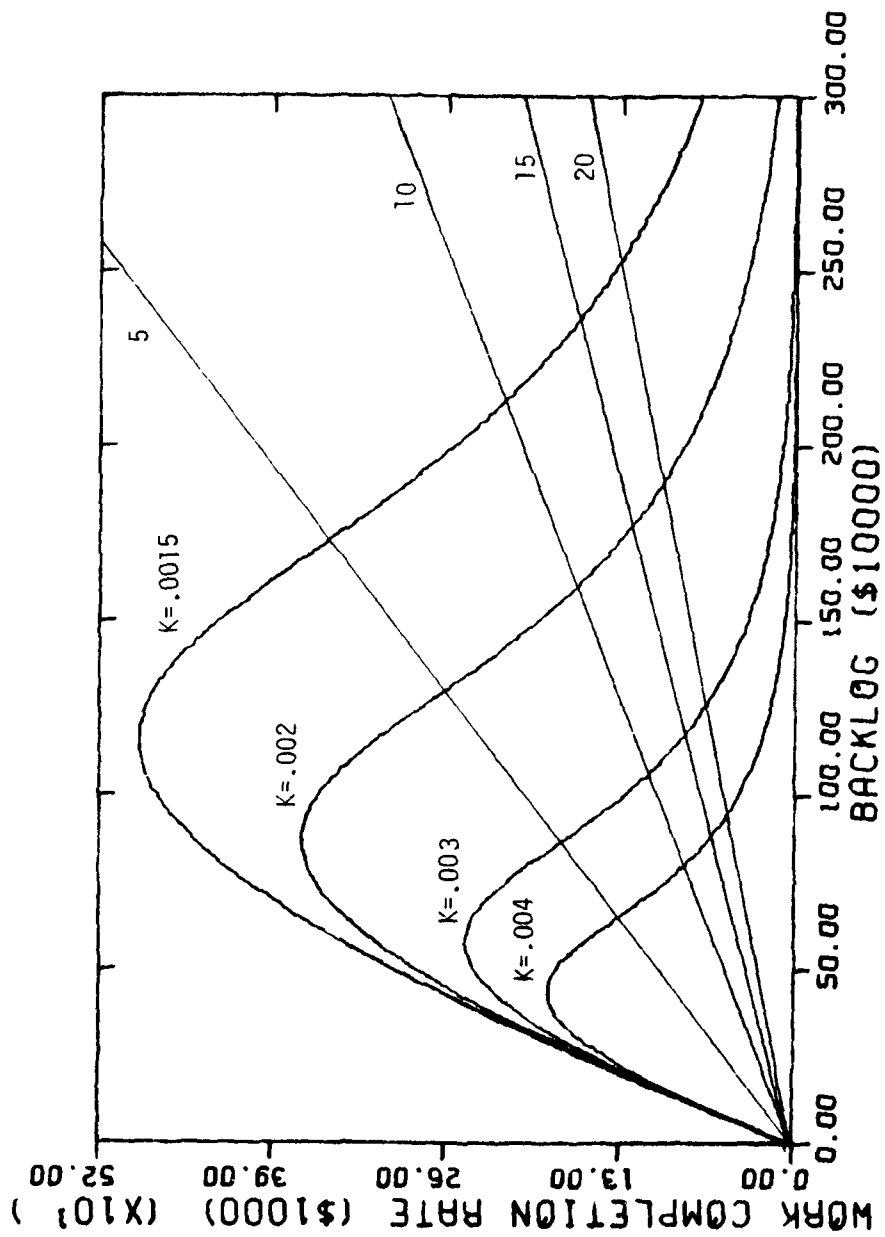
FIGURE E.11 -- PREDICTION BACKLOG CURVES, C=2.0

221
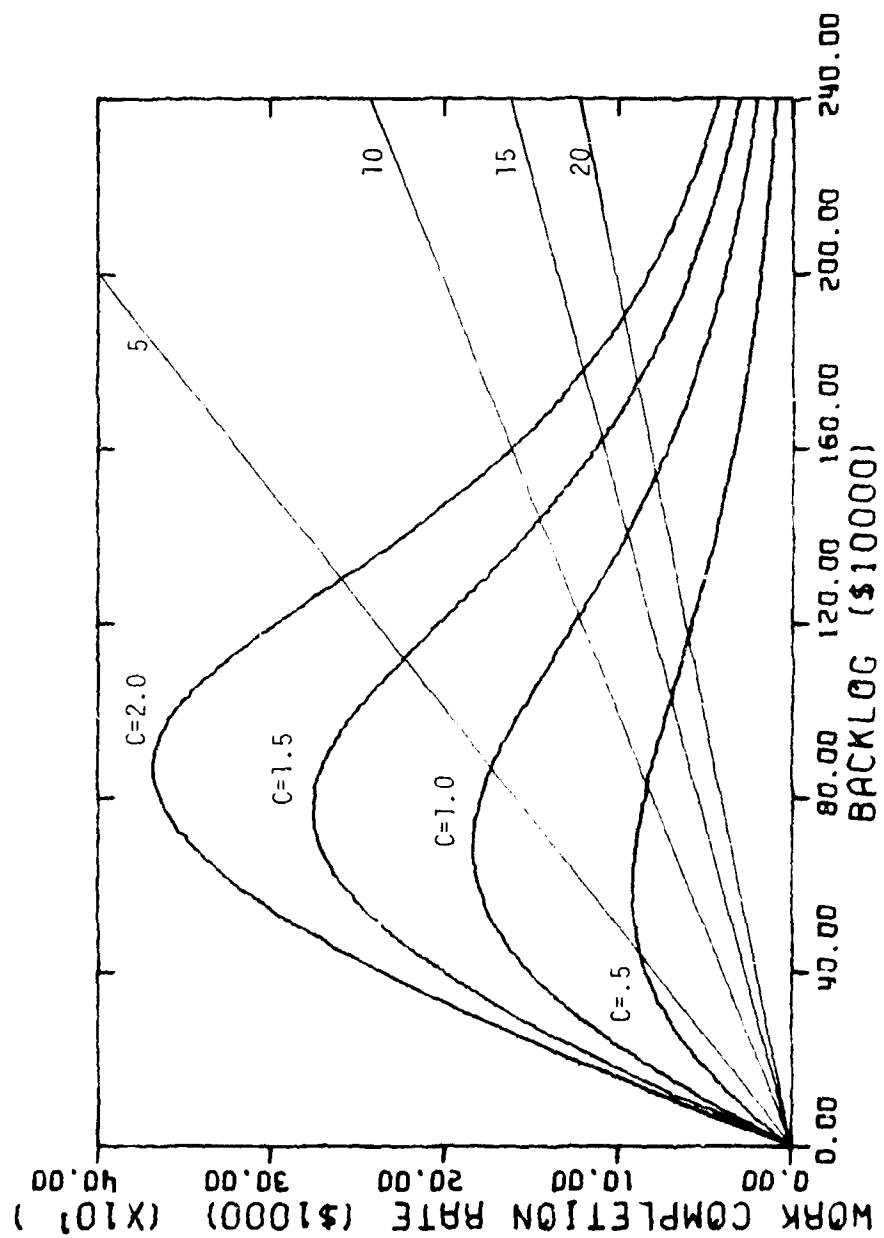
FIGURE E.12 -- PREDICTION BACKLOG CURVES, K=.002
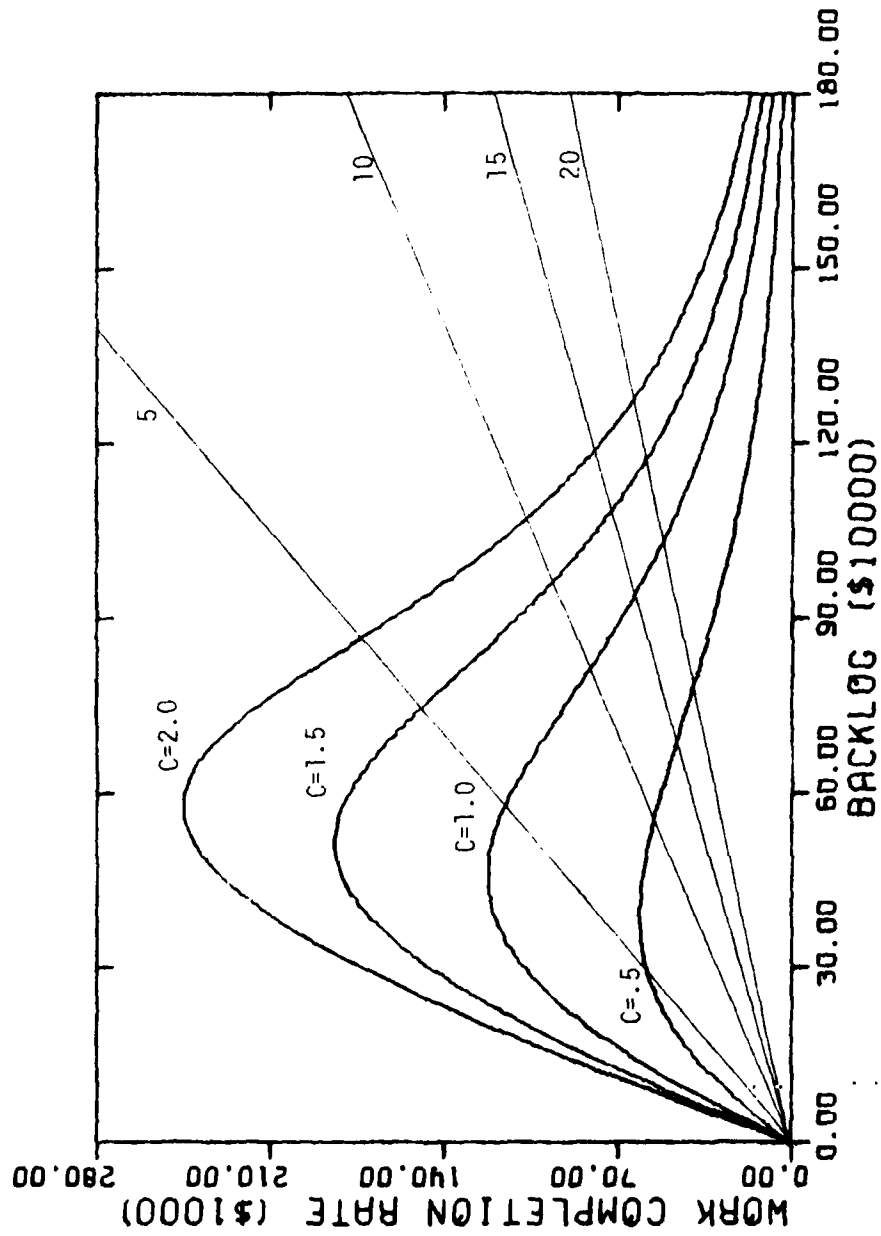
FIGURE E.13 -- PREDICTION BACKLOG CURVES, K=.003

223
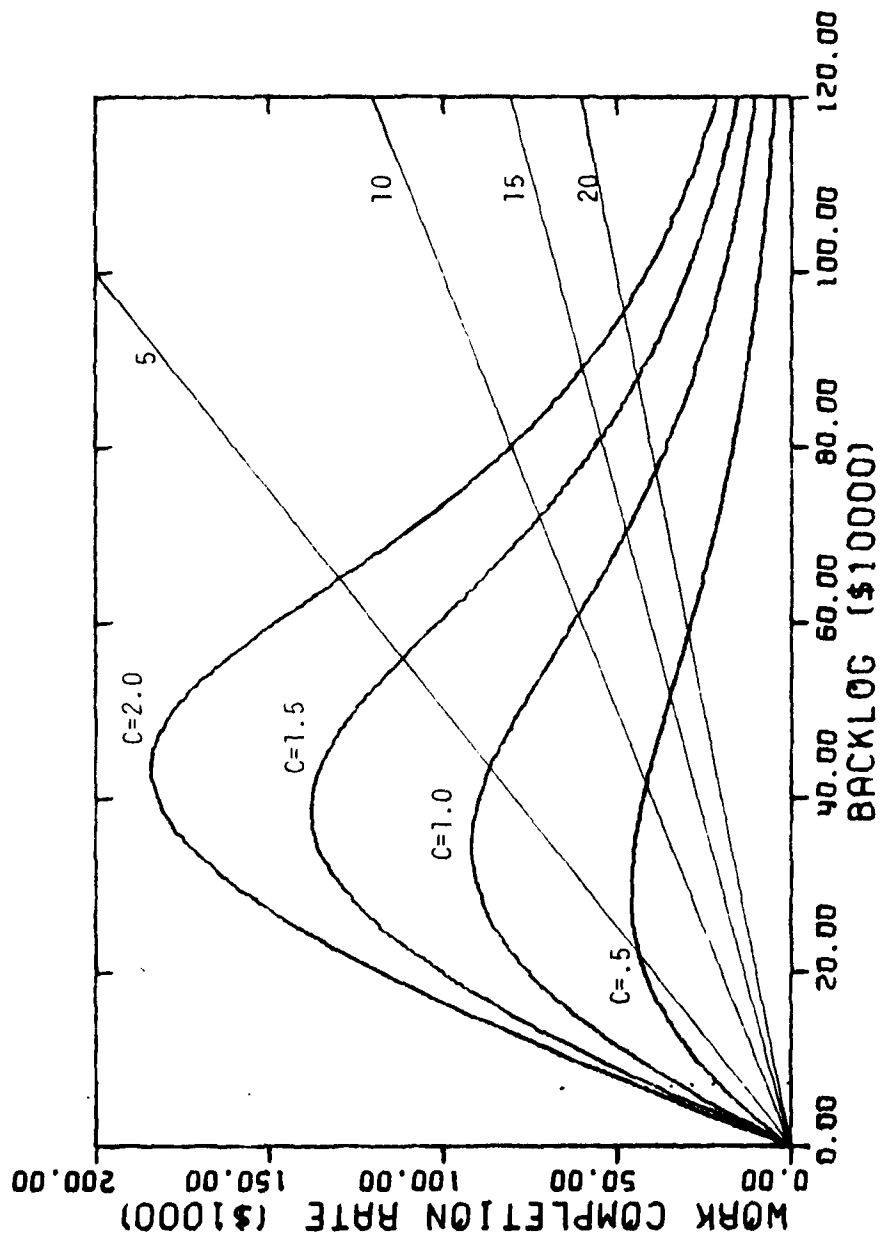
FIGURE E.14 -- PREDICTION BACKLOG CURVES, K=.004

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APPENDIX F

MISCELLANEOUS FIGURES

This appendix contains miscellaneous figures from the experiments reported in Chapter 5. Figures F.1 to F.6 present the results of experiments designed to identify the modulus of project size for a variety of operations defined by the backlog model. Figures F.7 and F.8 graphically present the analyses of the variable costs pricing methodology for markets C and E, respectively.

FIGURE F.2 -- IDENTIFYING THE MODULUS OF
PROJECT SIZE, K=.003 AND C=].5

FIGURE F.1 -- IDENTIFYING THE MODULUS OF
PROJECT SIZE, K=.003 AND C=2.0

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FIGURE F.4 -- IDENTIFYING THE MODULUS OF
PROJECT SIZE, K=.002 AND C=1.5

FIGURE F.3 -- IDENTIFYING THE MODULUS OF
PROJECT SIZE, K=.002 AND C=1.0

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FIGURE F.6 -- IDENTIFYING THE MODULUS OF
PROJECT SIZE, K=.004 AND C=1.5

FIGURE F.5 -- IDENTIFYING THE MODULUS OF
PROJECT SIZE, K=.002 AND C=2.0

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The graph shows "$1000" on the y-axis ranging from .9 to 2.3, and "MARKUP" on the x-axis ranging from M*+10% to M*+30%.

Labels on the graph:
- M*+28% from simulation
- M*+28%
- $\frac{1}{f(R(p))}$
- $\frac{.15X^{.375}}{100(1-p)^2}$
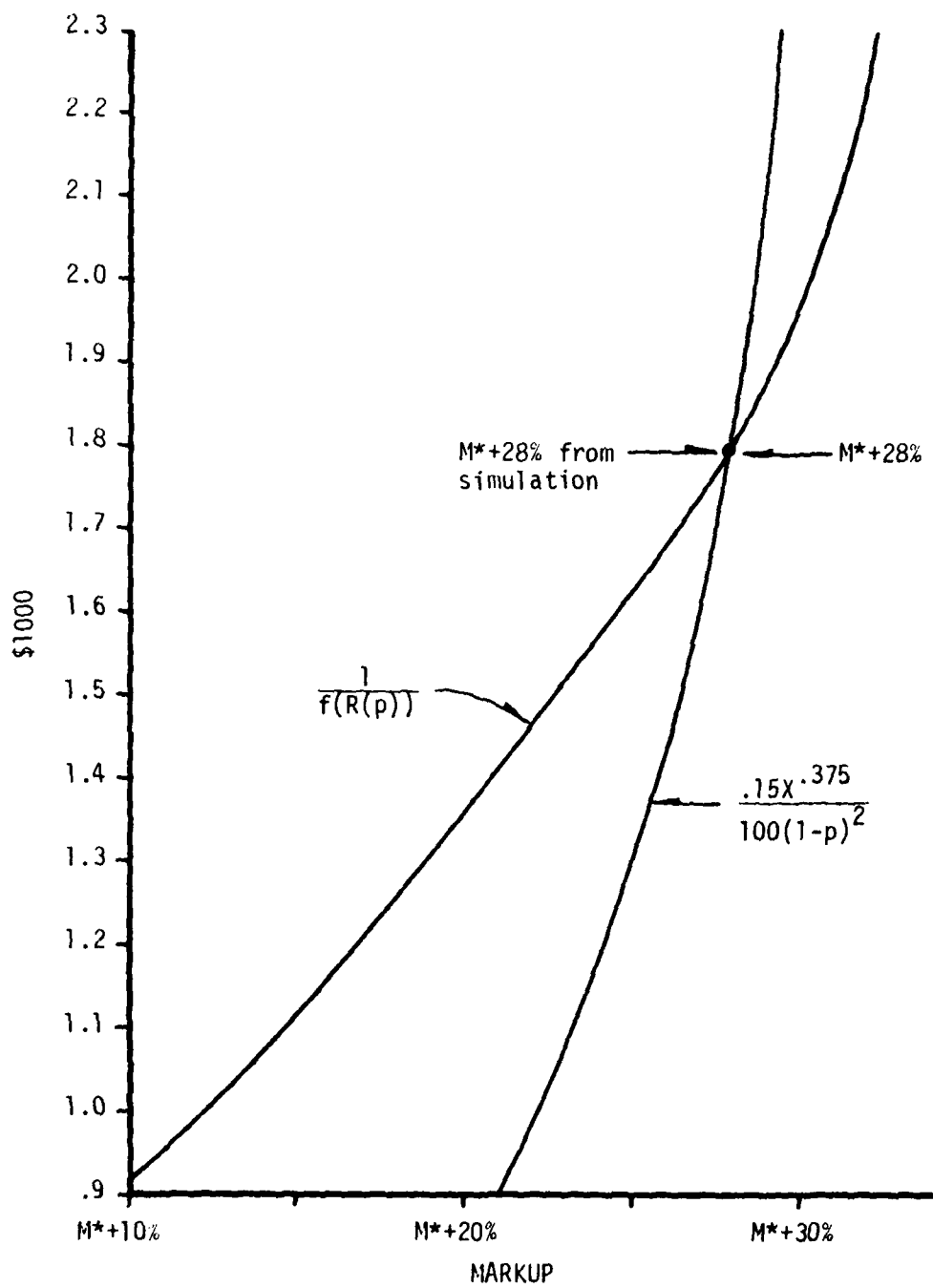
FIGURE F.7 -- GRAPHICAL ANALYSIS OF MARKET C

229
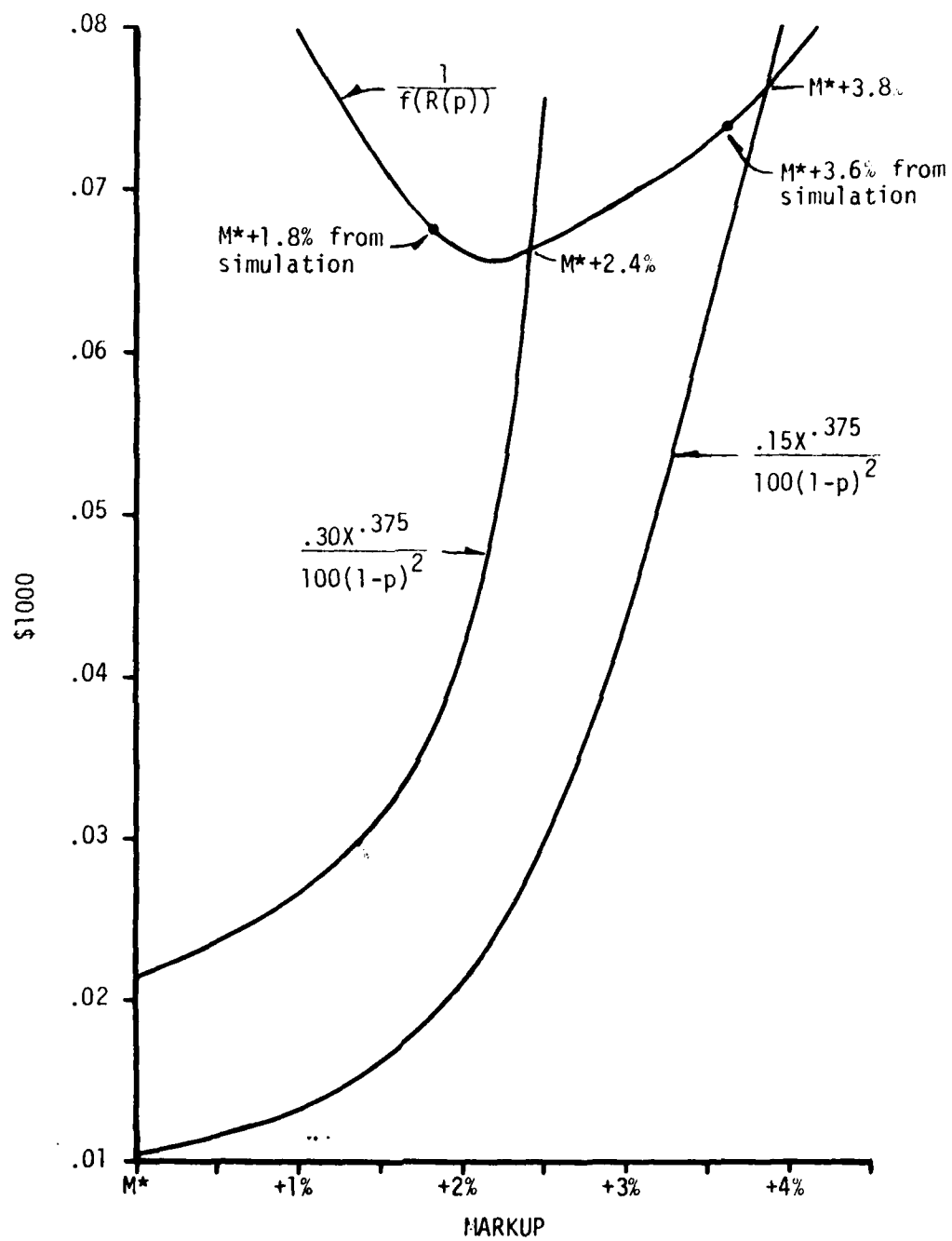
FIGURE F.8 -- GRAPHICAL ANALYSIS OF MARKET E

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APPENDIX G

TYPICAL BACKLOG OUTPUT

Figure G.1 shows the BACKLOG output summary of user specified information. This summary is printed for all options. Figure G.2 presents the short summary output for a single sample. Figure G.3 shows the long summary output for the sample presented in Figure G.2.

FIGURE G.1 -- SUMMARY OF USER SPECIFIED INFORMATION

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```
**********************************************
*                                            *
*    SUMMARY OF RESULTS FOR SAMPLE NO.  1     *
*                                            *
**********************************************
```

SAMPLE PARAMETERS:
_____

DECISION MAKING TIME INTERVAL (R):   0.2000E-02
PERCEIVED OPPORTUNITY FOR ACHIEVEMENT (C):   0.1500E-03
BONDING CAPACITY: 0.1350E-04
CONSTANT ESTIMATED PROJECT SIZE: 0.1000E-03
HIGH BACKLOG WITH OPS AT MAX EFFICIENCY: 0.1130E-04
RANGE OF EFFICIENT OPERATIONS EFFICIENCY: 0.1230E-04
LOW BACKLOG BEFORE MO IS MODIFIED: 0.1237E-04
HIGH BACKLOG BEFORE MO IS MODIFIED: 0.1130E-03
NUMBER OF PROJECTS BACKLOGGED IN START-UP: 0.1350E-04

ANALYSIS OF MARKET:
_____

NUMBER OF BID OPPORTUNITIES	SUBJECT CONTRACTOR BIDDING POLICY	TOTAL MARKET DOLLARS	TOTAL AWARDED DOLLARS	TOTAL POTENTIAL GROSS PROFITS
2134	RC	0.2604E+06	0.2604E+06	0.5722E-03
2134	RRO	0.2604E+06	0.2604E+06	0.5722E-03

ANALYSIS OF SUBJECT CONTRACTOR PERFORMANCE:

BIDDING POLICY	#PROJECT BID	#PROJECT WON	#PROJECT BID	ESTIMATED COSTS	GROSS SALES	ACTUAL COSTS	GROSS PROFITS	ESTIMATING COSTS	OVERHEAD COSTS	NET PROFITS
RC	252	85		0.0800E+04	0.9027E+04	0.8800E+04	0.2227E+04	0.2193E+03	0.617BE+03	0.1390E+04
RRO	252	85		0.0800E+04	0.9027E+04	0.8800E+04	0.2227E+04	0.2143E+03	0.617BE+03	0.1390E+04

ANALYSIS OF COMPETITOR PERCEIVED PERFORMANCE:

SUBJECT BID	#PROJECT BID	#PROJECT WON	PERCEIVED COSTS	SALES	PERCEIVED C PROFITS
RC	2132	2047	0.607E+06	0.6691E+06	0.604E+03
RRO	2134	2047	0.20E+06	0.2449E+06	0.644E+05

FIGURE G.2 -- BACKLOG OUTPUT: SHORT SUMMARY

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SAMPLE PARAMETERS:

```
*******************************************
     SUMMARY OF RESULTS FOR SAMPLE NO.  1
*******************************************
```

DECISION MAKING TIME INTERVAL (S):   0.1000E-02
PERCEIVED OPPORTUNITY FOR ACHIEVEMENT (C):   0.1500E-01
WORKING CAPITAL CONSTRAINT RATE (WMAX):   0.1350E-03
WORKING CAPACITY: 0.1320E-04
CONSTANT ESTIMATED PROJECT SIZE: 0.1000E-03
LOW BACKLOG WITH OPS AT MAX EFF: 0.1350E-03
MAX. UP EFFICIENT OPERATIONS: 0.1350E-04
MAX.UP EFFICIENT OPERATIONS EFFICIENCY: 0.1237E-04
LOW BACKLOG BEFORE RD IS MODIFIED: 0.1350E-03
HIGH BACKLOG BEFORE RD IS MODIFIED: 0.1350E-04
NUMBER OF PROJECTS BACKLOGGED IN START-UP: 0

ANALYSIS OF MARKET:

NUMBER OF BID OPPORTUNITIES	SUBJECT CONTRACTOR BIDDING POLICY	TOTAL MARKET DOLLARS	TOTAL AWARDED DOLLARS	TOTAL POTENTIAL GROSS PROFITS
2132	RD	0.2600E+06	0.2600E+06	0.4722E+05
2132	RD0	0.2600E+06	0.2600E+06	0.4722E+05

GENERATED DISTRIBUTION OF ESTIMATED JOB SIZE:

MEAN	VARIANCE	THIRD MOMENT	FOURTH MOMENT	SKEWNESS	KURTOSIS
0.1000E+03	0.0	0.0	0.0	0.0	0.0

GENERATED DISTRIBUTION OF MONTHLY ARRIVAL RATE OF BID OPPORTUNITIES:

MEAN	VARIANCE	THIRD MOMENT	FOURTH MOMENT	SKEWNESS	KURTOSIS
0.3555E+02	0.7782E+01	-.3670E+01	0.1253E+03	-.1040E+00	0.2069E+01

FIGURE G.3 -- BACKLOG OUTPUT: LONG SUMMARY

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ANALYSIS OF SUBJECT CONTRACTOR PERFORMANCE:

BIDDING &PROJECT &PROJECT ESTIMATED GROSS   ACTUAL   GROSS   ESTIMATING   OVERHEAD   NET
POLICY   BID   NUM   COSTS   SALES   COSTS   PROFITS   COSTS   COSTS   PROFITS
MB   252   85   0.6800E+04 0.9047E+04 0.6800E+04 0.2227E+04 0.2193E+03 0.0178E+03 0.1390E+04
MB+   252   85   0.6800E+04 0.9047E+04 0.6800E+04 0.2227E+04 0.2193E+03 0.0178E+03 0.1390E+04

DISTRIBUTION OF BACKLOG OF WORK (END OF EACH MONTH):

BIDDING   THIRD   FOURTH
POLICY   MEAN   VARIANCE   MOMENT   MOMENT   SKEWNESS   KURTOSIS
MB   0.1108E+04 0.8312E+03 0.0   0.1240E+07 0.0   0.1794E+01
MB+   0.1108E+04 0.8312E+03 0.0   0.1240E+07 0.0   0.1794E+01

DISTRIBUTION OF WORK COMPLETE RATE (BEGINNING OF EACH MONTH):

BIDDING   THIRD   FOURTH
POLICY   MEAN   VARIANCE   MOMENT   MOMENT   SKEWNESS   KURTOSIS
MB   0.1350E-03 0.0   0.0   0.0   0.0   0.0
MB+   0.1350E-03 0.0   0.0   0.0   0.0   0.0

DISTRIBUTION OF ESTIMATED COSTS:

BIDDING   THIRD   FOURTH
POLICY   MEAN   VARIANCE   MOMENT   MOMENT   SKEWNESS   KURTOSIS
MB   0.1000E-03 0.0   0.0   0.0   0.0   0.0
MB+   0.1000E-03 0.0   0.0   0.0   0.0   0.0

DISTRIBUTION OF BIDS:

BIDDING   THIRD   FOURTH
POLICY   MEAN   VARIANCE   MOMENT   MOMENT   SKEWNESS   KURTOSIS
MB   0.1328E+03 0.2473E-02 0.1230E-03 0.6115E-05 0.1000E+01 0.1000E+01
MB+   0.1328E+03 0.2473E-02 0.1230E-03 0.6115E-05 0.1000E+01 0.1000E+01

DISTRIBUTION OF ACTUAL COSTS:

BIDDING   THIRD   FOURTH
POLICY   MEAN   VARIANCE   MOMENT   MOMENT   SKEWNESS   KURTOSIS
MB   0.1000E+03 0.0   0.0   0.0   0.0   0.0
MB+   0.1000E+03 0.0   0.0   0.0   0.0   0.0

FIGURE G.3 -- BACKLOG OUTPUT: LONG SUMMARY (Continued)

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DISTRIBUTION OF GROSS PROFITS:

BIDDING POLICY	MEAN	VARIANCE	THIRD MOMENT	FOURTH MOMENT	SKEWNESS	KURTOSIS
MB	0.3275E+02	0.5590E-06	-.4180E-09	0.3125E-12	-.1000E+01	0.1000E+01
MBB	0.3275E+02	0.5590E-06	-.4180E-09	0.3125E-12	-.1000E+01	0.1000E+01

DISTRIBUTION OF NET PROFITS:

BIDDING POLICY	MEAN	VARIANCE	THIRD MOMENT	FOURTH MOMENT	SKEWNESS	KURTOSIS
MB	0.2282E+02	0.6262E-05	-.1562E-07	0.3922E-10	-.1000E+01	0.1000E+01
MBB	0.2282E+02	0.6262E-05	-.1562E-07	0.3922E-10	-.1000E+01	0.1000E+01

ANALYSIS OF COMPETITOR PERCEIVED PERFORMANCE:

SUBJECT BID	#PROJECT BID	#PROJECT WON	PERCEIVED COSTS	SALES	PERCEIVED G PROFITS
MB	2132	2047	0.2047E+06	0.2491E+06	0.4444E+05
MBB	2132	2047	0.2047E-06	0.2491E+06	0.4444E+05

DISTRIBUTION OF PERCEIVED COSTS:

BIDDING POLICY	MEAN	VARIANCE	THIRD MOMENT	FOURTH MOMENT	SKEWNESS	KURTOSIS
MB	0.1000E+03	0.0	0.0	0.0	0.0	0.0
MBB	0.1000E+03	0.0	0.0	0.0	0.0	0.0

DISTRIBUTION OF BIDS:

BIDDING POLICY	MEAN	VARIANCE	THIRD MOMENT	FOURTH MOMENT	SKEWNESS	KURTOSIS
MB	0.1217E+03	0.5316E+03	0.2881E+04	0.7403E+06	0.2351E+00	0.2620E+01
MBB	0.1217E+03	0.5316E+03	0.2881E+04	0.7403E+06	0.2351E+00	0.2620E+01

DISTRIBUTION OF PERCEIVED GROSS PROFITS:

BIDDING POLICY	MEAN	VARIANCE	THIRD MOMENT	FOURTH MOMENT	SKEWNESS	KURTOSIS
MB	0.2171E+02	0.4619E+03	-.9927E+03	0.2134E+06	-.1000E+01	0.1000E+01
MBB	0.2171E+02	0.4619E+02	-.9427E+04	0.2134E+06	-.1000E+01	0.1000E+01

FIGURE G.3 -- BACKLOG OUTPUT: LONG SUMMARY (Continued)

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